ملزمة (5) - ١٠

Protection (2)

الفرقة الرابعة كهرباء قوى

للاستعلام أتصل على : ٠١٠١٢٤٠٢٦٧

مكتبة لؤلؤة الهندسة

شارع سكة علام – العباسية

كلية الهندسة – جامعة عين شمس

مع تمنياتنا لكم بالنجاح والتوفيق

Protection

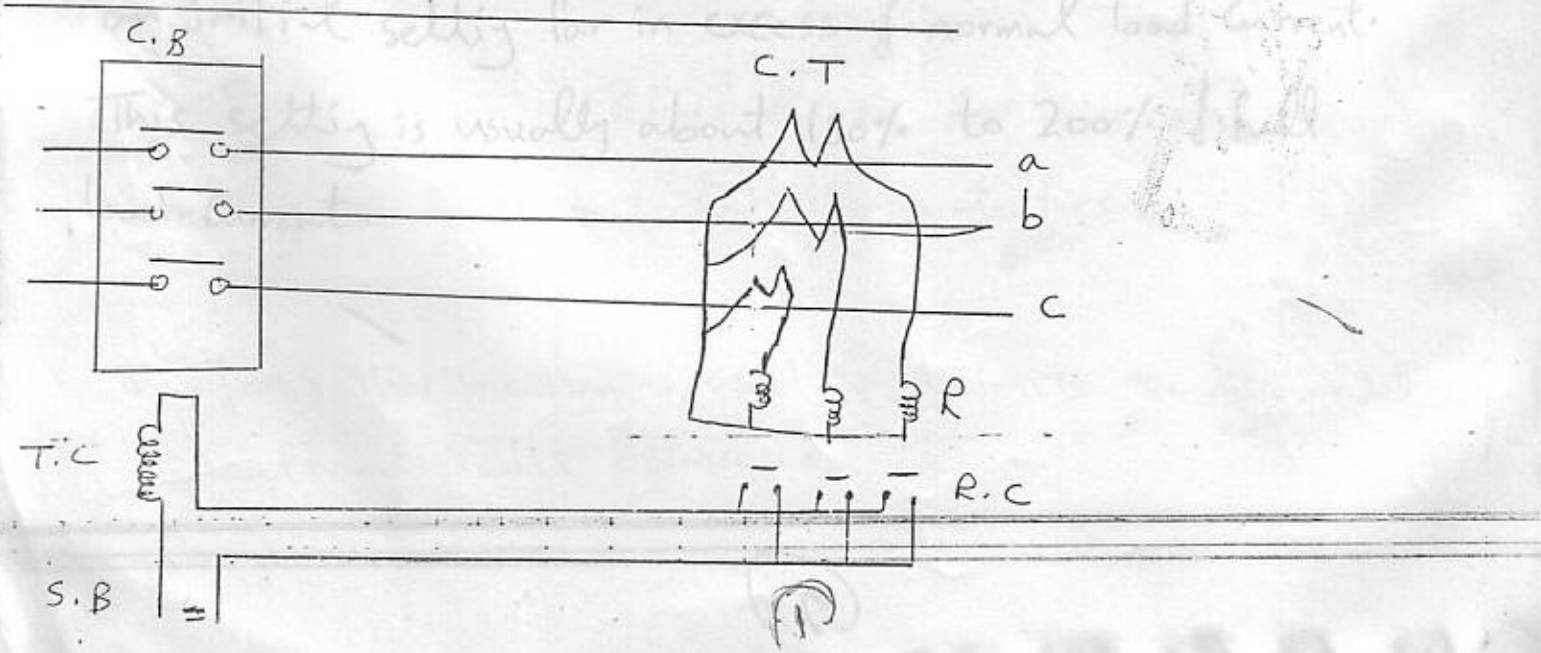
Protection Applications

Pilotless Protective Systems

These are the Protective systems which do not employ Pilot wires. The following are the main types of Pilotless Systems :-

1. Simple overcurrent protection.
2. Graded type overcurrent protection.
3. Earth leakage protection.
4. Combined Leakage and over-current Protection.
5. Protection of Parallel feeders.

(1) Simple Overcurrent Protection :-



- The relays employed are of the induction type.
- This system will respond to faults between phases or from phase to earth.
- The Relay contacts are Connected in parallel so that if any relay operates its Relay Contact will closed thus energizing the tripping coil of Circuit breaker.

Advantages of this system :-

1. In Common with all Pilotless Systems, it eliminates the cost of Pilot Cable & therefore is not expensive.
2. Accurate ~~—~~ of transformers, which was required in Pilot Systems is not necessary.

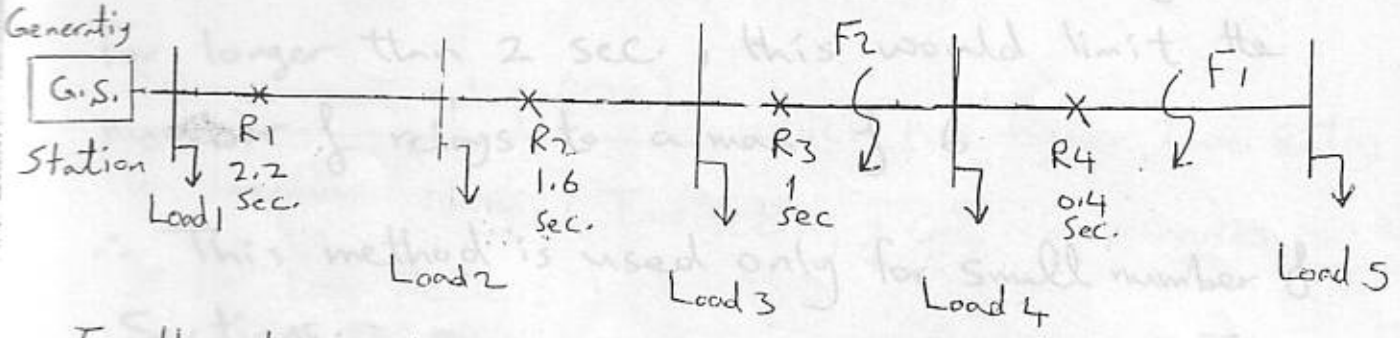
Disadvantages of this system :-

1. It is not very sensitive as the relays must have an initial setting far in excess of normal load current. This setting is usually about 150% to 200% of full load current.

Graded Type over-current Protection :- (3)

In these systems each relay is assigned a certain time setting. The most important types of graded type over-current protection are :

a) Radial Feeder Protection :-



- In this type the relays are adjusted to have a decreasing time setting with the increase of distance from the G.S.

- For a fault at F1 : All relays will sense the presence of the fault but R4 will operate First (R4 has smallest time setting) and clear the faults

- For a Fault at F2 : Relays R_1, R_2, R_3 will sense the presence of the fault but R_3 will operate first

Therefore, this method is used to minimize the disconnected loads at Fault occurrence

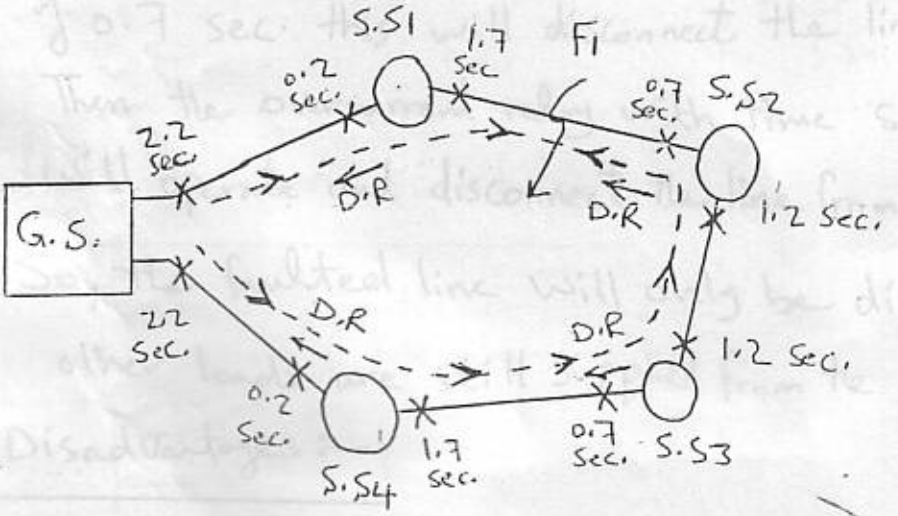
isadvantages :—

① Not very sensitive.

② To obtain proper descrimination (2 relays don't operate at the same time), the setting time of successive relays should differ by 0.4 → 0.6 sec., also the setting of the first relay should not exceed 2.2 sec. as the short circuit shouldn't be kept on the generator for longer than 2 sec., this would limit the number of relays to a max. of 6

∴ This method is used only for small number of sections.

b) Protection of Ring Main :—



Overcurrent relay
O.C

Directional overcurrent relay

The great advantage of the ring main system is supply continuity to the loads in case of fault occurrence

* Each substation is protected by two relays:

1. Directional relay (D.R) which has lower time setting and operates only for fault currents in the direction of the arrow → (Time setting of D.R increases as we go far from the G.S.)

2. Overcurrent relay (O.C) which has higher time setting than directional relay. (Time setting of O.C relay decreases as we go far from the G.S.)

For a fault at F1 the direction of the current is as shown in the figure by dotted lines.

* The first relay to operate is D.R with the time setting of 0.7 sec. this will disconnect the line from one side. Then the overcurrent relay with time setting of 1.7 sec will operate and disconnect the line from the other side.

So, the faulted line will only be disconnected and the other loads are still supplied from the G.S.

Disadvantages:-

1. Same disadvantages as in case of radial feeders.
2. Using potential transformers which are necessary for the directional relays.

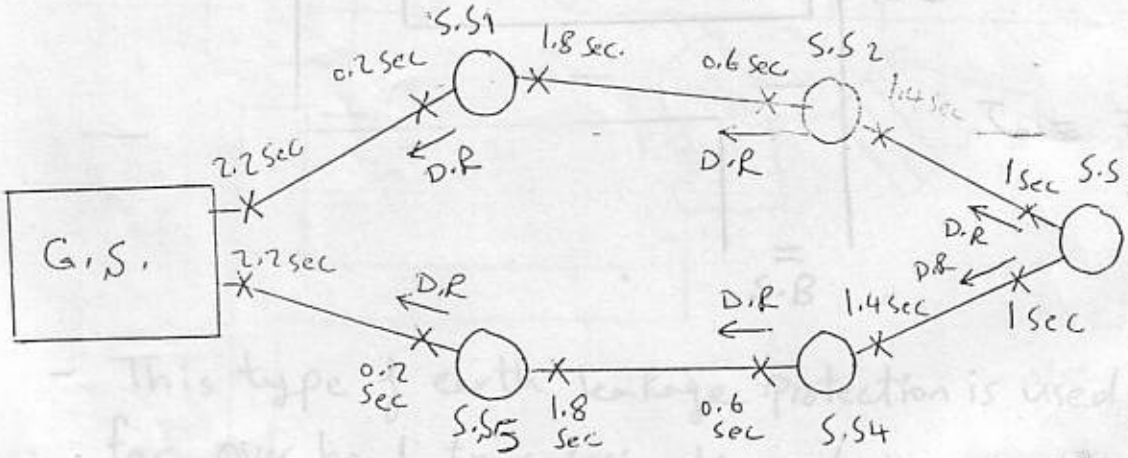
How to determine time setting of Relays ?

① نبدأ بتعيين time setting of Directional relays ← D.R ونبدأ بأول مرة: G.S ~ ونبدأ عادة بـ 0.2 sec ثم نزيد في الـ time setting طبيعي حتى نصل إلى آخر Sub-station بعيدة عن G.S (clockwise, anticlockwise) 0.4 – 0.6 sec.

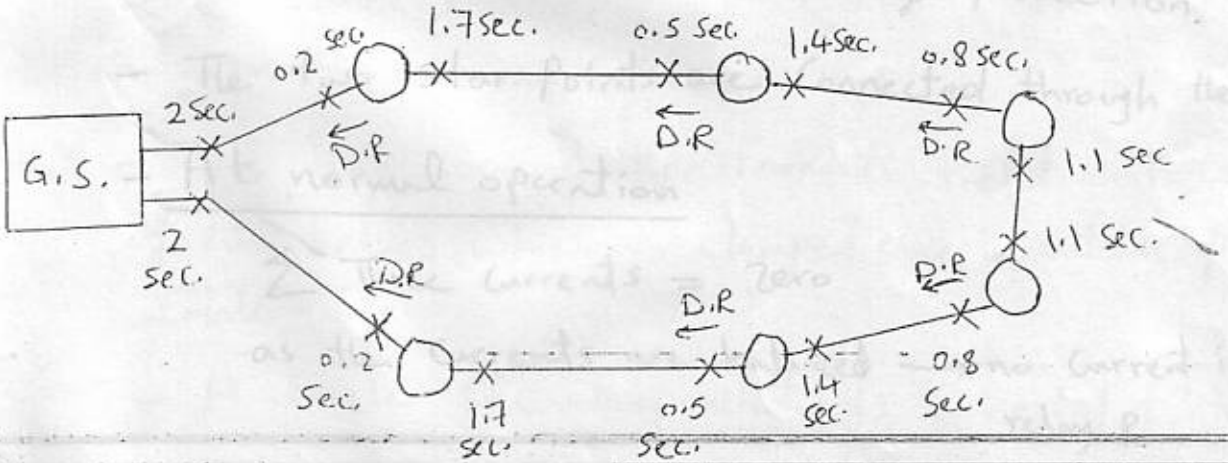
② نبدأ بتعيين time setting of Overcurrent Relays ← Substation آخر ~ نبدأ

ثم نتحرك حتى نصل إلى G.S (clockwise, anticlockwise)

Ex :- If we have 5 Substations

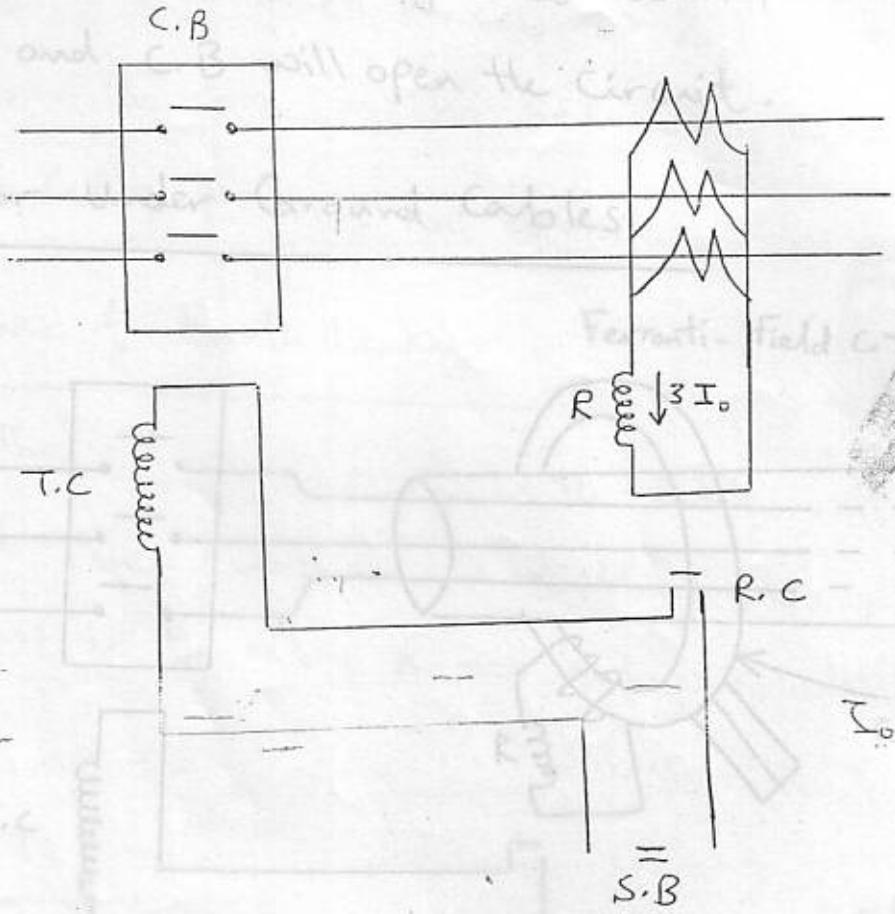


If we have 6 substations



c) Earth Leakage Protection

a) For Over Head T.L (OHTL)



I_0 ≡ Zero Sequence Current

- This type of earth leakage protection is used mainly for over head transmission lines (OHTL)
- 3 Current transformers (star connected at both ends) are used. Used for earth leakage protection
- The two star points are connected through the relay R
- At normal operation

$\sum$ Three currents = zero

as the currents are balanced → no current in the relay R

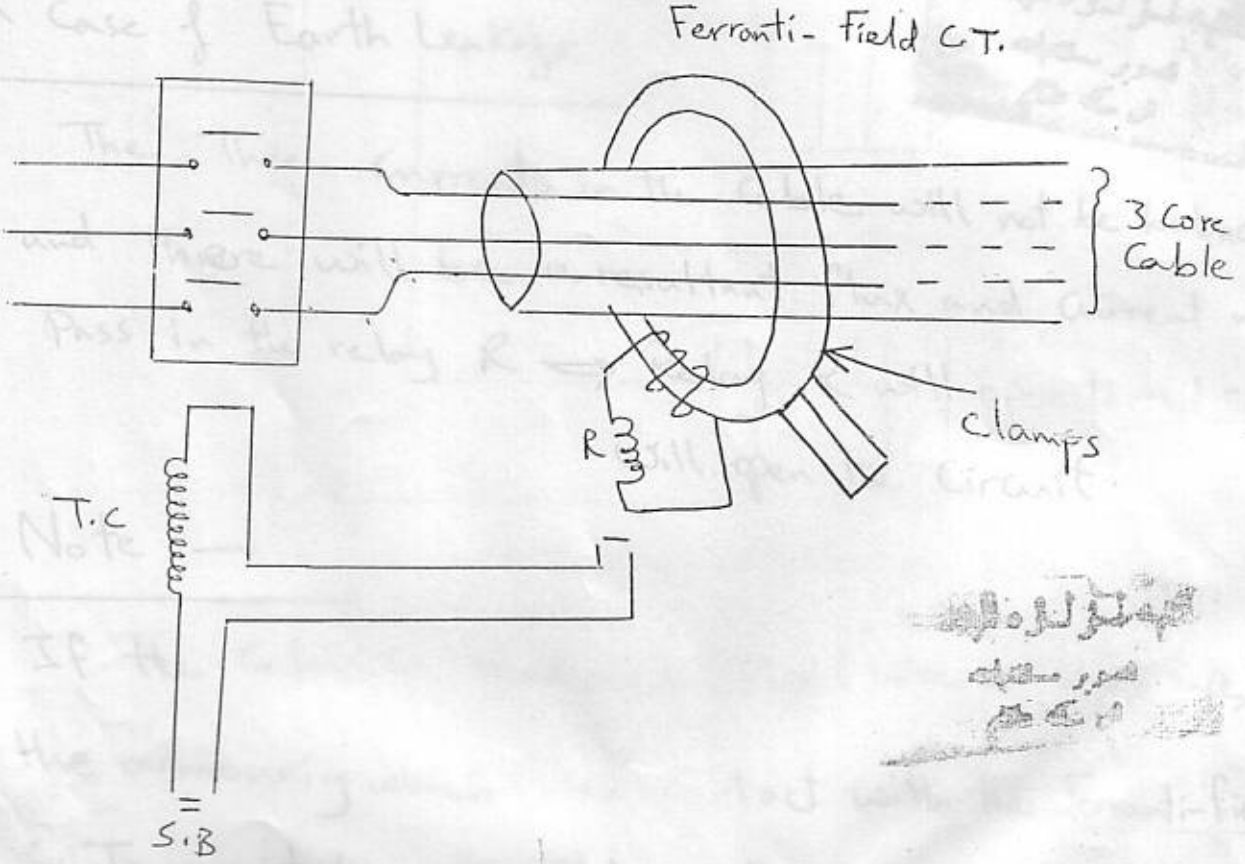
→ No relay operation

- In case of Earth Leakage

Σ Three Currents $\neq$ Zero

and a current of $3I_o$ will pass through relay R and C.B will open the circuit.

b) For under Ground Cables



- This type of earth leakage protection is mainly used for under Ground Cables.
- The iron core of the Ferranti Field C.T consists of two halves which are clamped over the outside of the Cable.
- A single secondary winding is connected to the relay (R)

1- Normal operation

The Three Currents in the Cable will be balanced and Produced three balanced fluxes $\Rightarrow \Sigma$ flux $= 0$, So there is no flux in the core $\Rightarrow$ no Secondary Current in the relay

$\Rightarrow$ Relay R will not operate.

In Case of Earth Leakage

The Three Currents in the Cable will not be balanced and there will be a resultant flux and Current will Pass in the relay R $\Rightarrow$ Relay R will operate and will open the Circuit.

Note :—

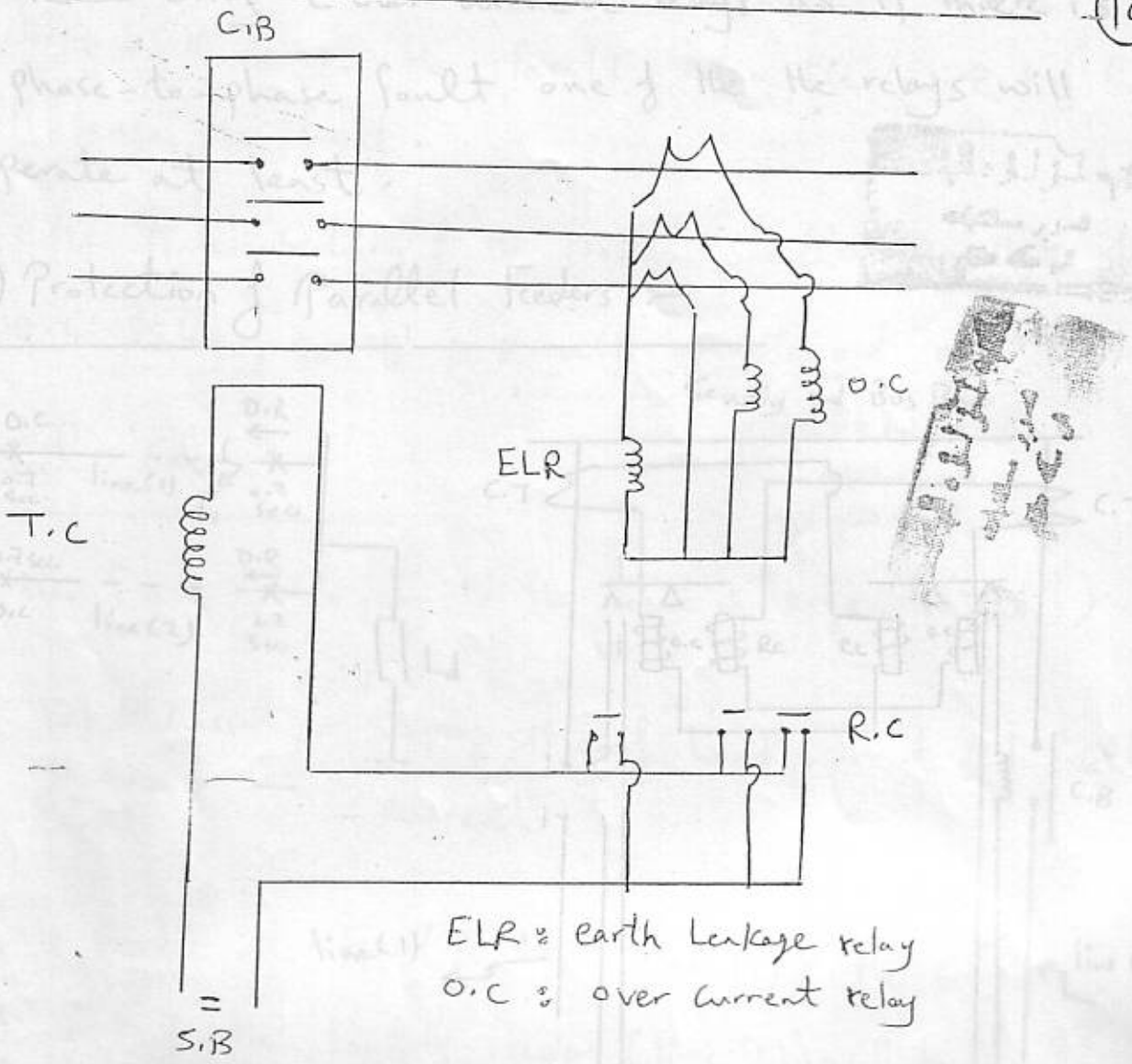
If the Cable is armoured (Steel wire or steel tape) the armouring which is in contact with the Ferranti-field C.T. must be removed as the armouring will Prevent the flux to pass in the core (why ??)

As the armouring is earthed So the leakage or earth Current will Pass through the armouring

$\Rightarrow$ Σ Current in the 3 Core Cable & armouring = Zero

$\Rightarrow$ No flux in Core $\Rightarrow$ Relay will not operate even though there is earth leakage

4) Combined Leakage and Over-Current Protection:

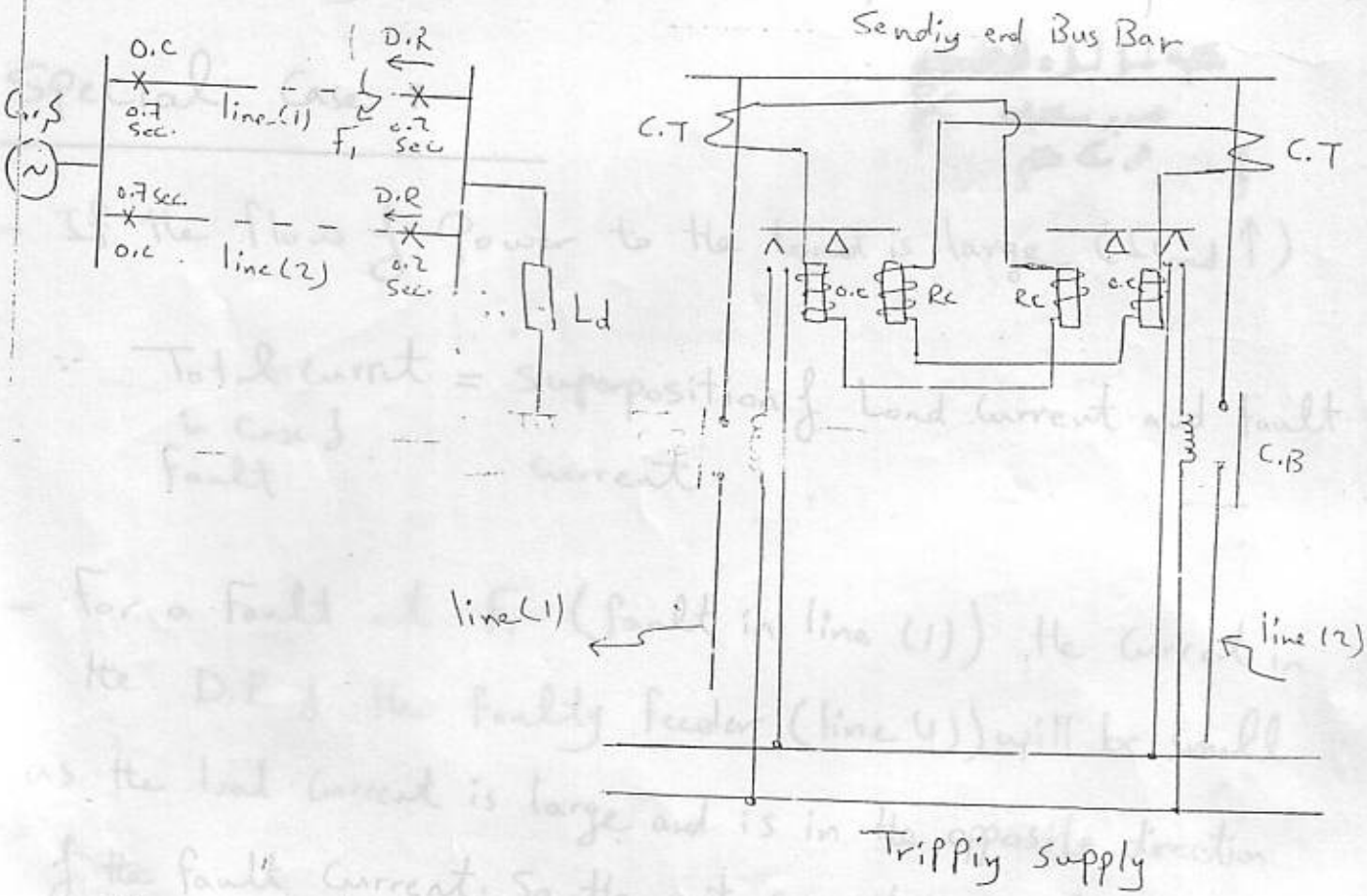


- Earth leakage relay protects against earth faults since it operates with the resultant current which is zero except when there is a fault to earth.
- over current relays protect against phase to phase faults as the over current relay operates when the current exceeds the minimum current setting of the over current protection.

Note :-

- we need only 2 over current relays as if there is a phase-to-phase fault one of the the relays will operate at least.

(5) Protection of Parallel Feeders :-



- In Protection of Parallel feeders, directional relays (D.R) are used at the receiving end to Prevent the reverse of Power also. (O.C) over current relays are used at the Sending end.

- The time setting of the directional relay is smaller than that of the over current relay.

- In case of fault at F_1, the 2 over current relays will sense the fault, also the (D.R) of line (1) will sense the fault.

- As the time setting of the D.R is smaller than that of the O.C Relay, so the D.R will operate and open the C.B.

Special Case :-

- If the flow of Power to the load is large (I_{load} ↑)

∴ Total current = Superposition of Load current and fault current
in case of fault

- For a fault at F_1 (fault in line (1)) the current in the D.R of the faulty feeder (line (1)) will be small as the load current is large and is in the opposite direction of the fault current, so the net current is small.

⟹ The D.R of the faulty line may not operate the O.C relays will operate at the same time.

To overcome this Problem :-

- Biased beam relays are used at the sending end.

- The connection of the biased beam relays in such that the feeder with the higher current will only be disconnected.

As shown in the figure the connection is such that the current through the operating coil is fed from the feeder to be protected and the current through the restraining coil is fed from the other feeder ⟹ operation of one O.C. relay will prevent the other from operation.

Protection (2)
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مع تمنياتنا لكم بالنجاح والتوفيق

أحمد لؤي الحسن
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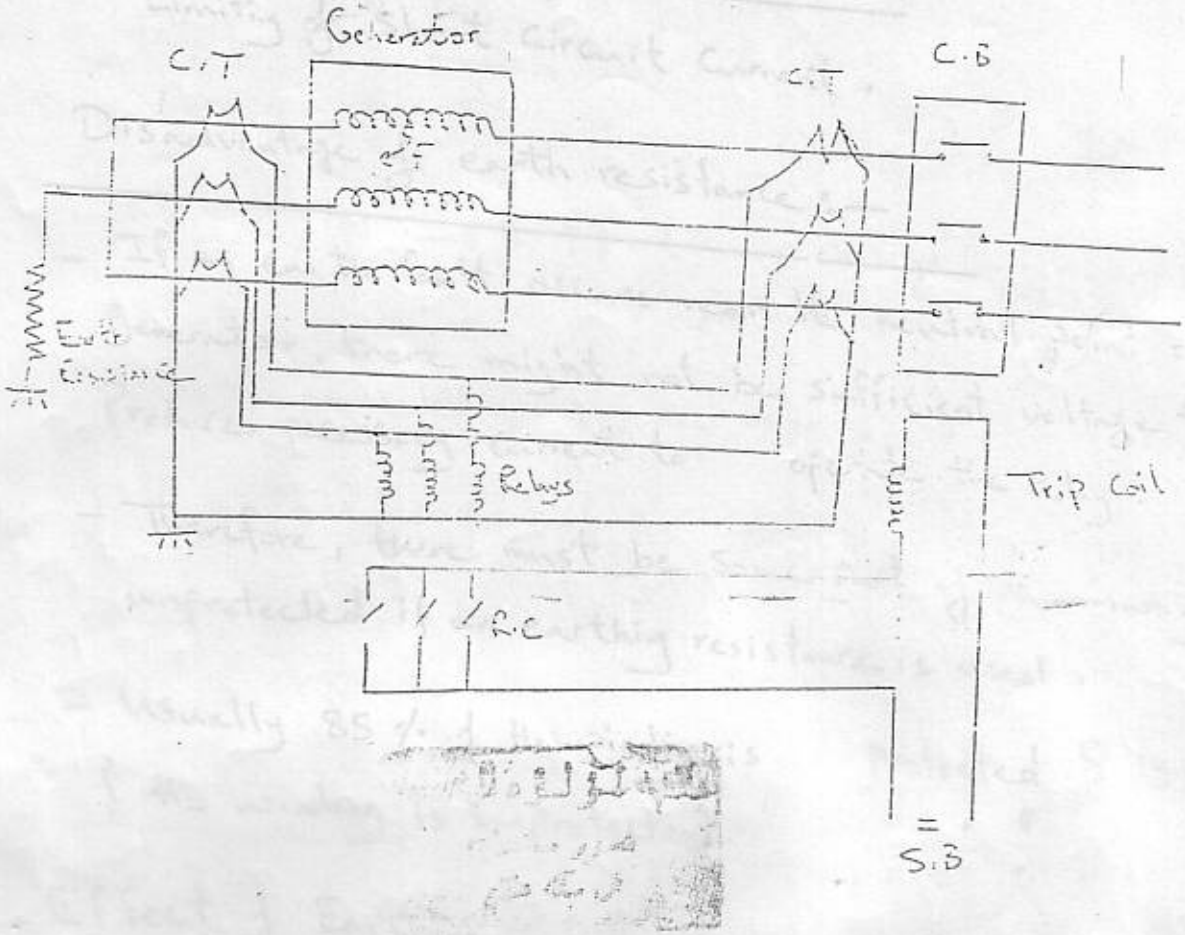
Protection of Alternators

① Merz-Price Differential Protection



- This method is used for Protection of generators above 1000 KVA.

- Two sets of 3 current transformers are used, each set is connected in star and the star points of the two sets are connected together.

- For a fault "F" at the generator windings the current will differ in the two current transformers, a current will pass in the corresponding relay ⇒ the C.B will operate

- An earth resistance is connected between the star point of the generator windings and earth.

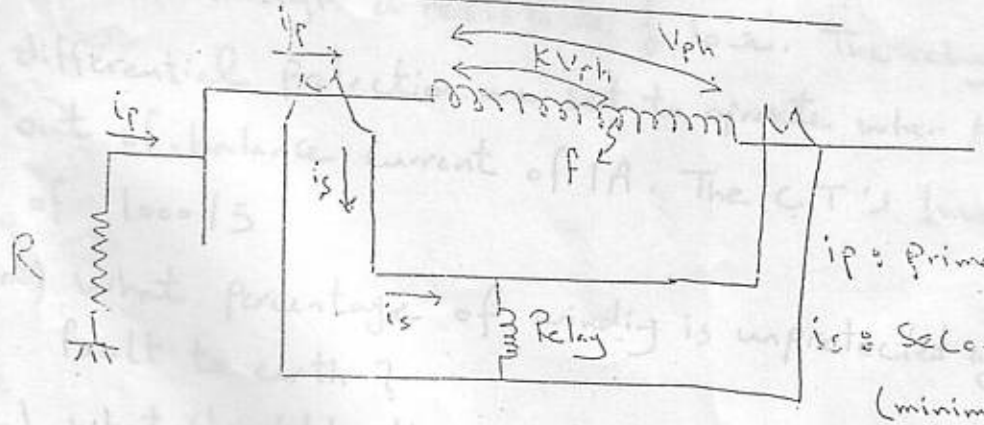
Advantage of earth resistance :—

Limiting of short circuit current.

Disadvantage of earth resistance :—

- If an earth fault occurs near the neutral point of the generator, there might not be sufficient voltage to produce necessary current to operate the relay.
- Therefore, there must be some part of the winding unprotected if an earthing resistance is used.
- Usually 85% of the winding is protected & 15% of the winding is unprotected.

Effect of Earthing Resistance :—



ip : Primary Current

is : Secondary Current (minimum current required to operate the relay)

$$i_p = \frac{KV_{ph}}{R + KZ}$$, Z : impedance of the winding

usually $Z << R$

$$\therefore i_p = \frac{KV_{ph}}{R}$$

as $R \uparrow\uparrow \rightarrow K \uparrow\uparrow$ (There will be larger unprotected part of the winding)

K ≡ unprotected part of the winding

1 − K ≡ protected part of the winding

Notes:

$0.1 \leq K \leq 0.15$

Example :-

The neutral point of a 10 KV, 3phase alternator is earthed through a resistance of 10Ω. The relays used for differential protection are set to operate when there is an out of balance current of 1A. The C.T's have a ratio of 1000/5

a) What percentage of winding is unprotected against fault to earth?

b) What should be the minimum value of earthing resistance to give 90% protection to each phase winding?

Solution :—

a) $V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{I_o}{\sqrt{3}} = 5.774\ KV$

$i_s = 1\ A \Rightarrow i_p = 1 \cdot \frac{1000}{5} = 200\ A$

$i_p = \frac{K V_{ph}}{R} \Rightarrow 200 = \frac{K\,(5.774 \cdot 10^3)}{i_o}$

$K = 0.346$

∴ Percentage of unprotected winding = 34.6 %

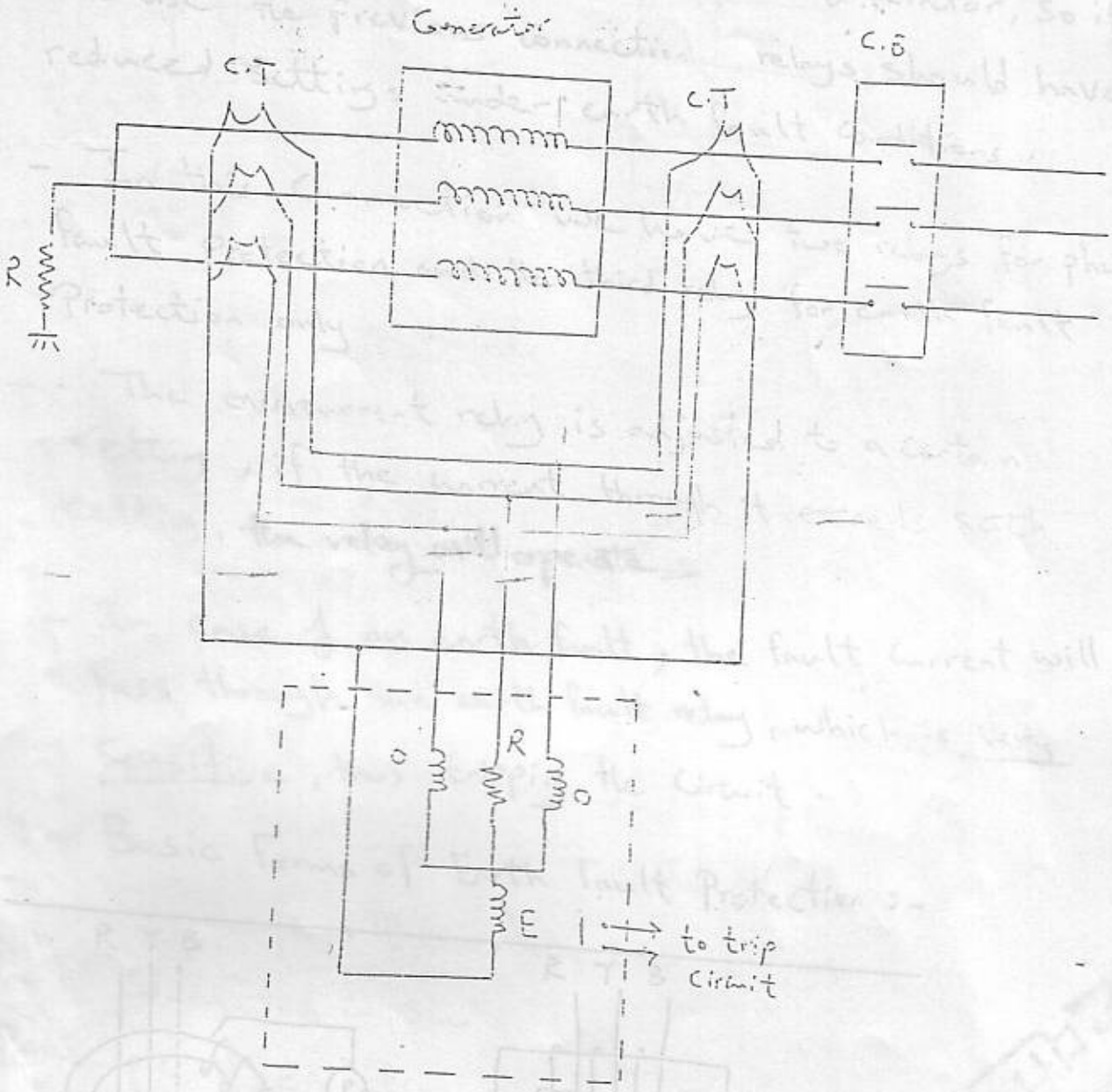
∴ Percentage of protected winding = 65.4 %

b) For $K = 0.1$

$i_p = \frac{K V_{ph}}{R} \Rightarrow 200 = \frac{(0.1)(5.774 \cdot 10^3)}{R}$

$R = 2.887\ \Omega$

Differential Protection Including Earth leakage Protection



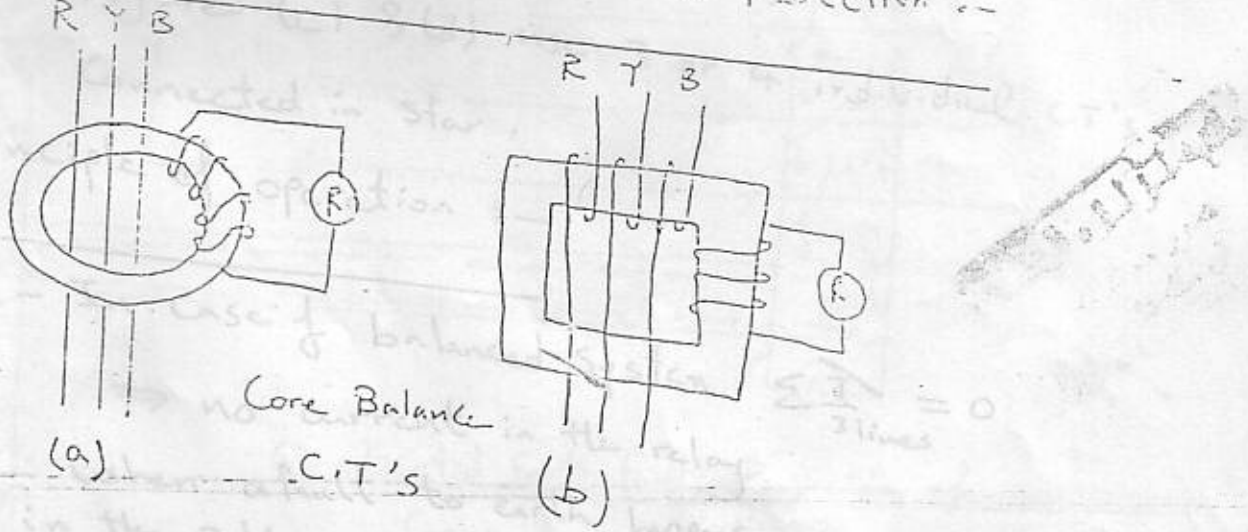
O = Phase fault Relay (overcurrent)

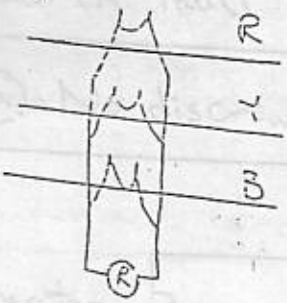
E = Earth fault Relay

R = Balancing Resistance

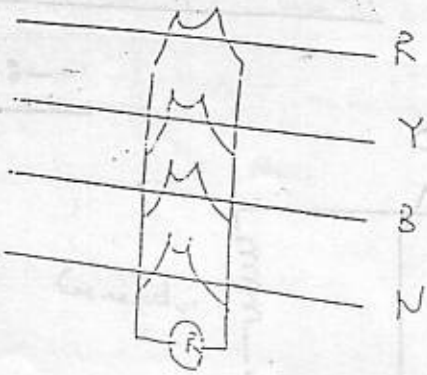
- Due to special applications, the earthing resistance is high and limits the earth fault current to a value less than the full load current of the generator, so if we use the previous connection relays should have reduced settings under earth fault conditions.
- In this connection we have two relays for phase fault protection and the third relay for earth fault protection only.
- The overcurrent relay is adjusted to a certain setting, if the current through it exceeds such setting, the relay will operate.
- In case of an earth fault, the fault current will pass through the earth fault relay, which is very sensitive, thus tripping the circuit.

Basic forms of Earth Fault Protection :-





(c)



(d)

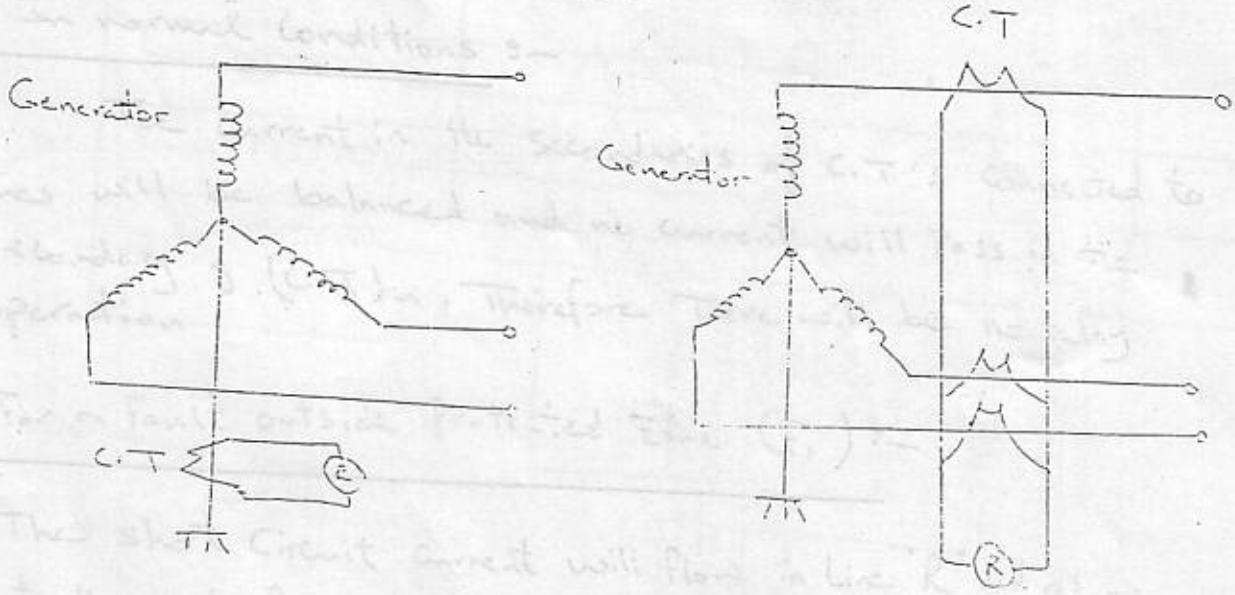
- Earth fault is mainly due to insulation failure of one phase.
- Basic Forms of earth fault protection are shown in the figures above.
- In figures (a) & (b) the earth leakage relay is connected to the secondary circuits of one C.T (Core Balance Current Transformer)
- Figure (c) & (d) use 3 or 4 individual C.T's connected in star.

Principle of operation :-

- In case of balanced system $\sum_{3\text{lines}} \vec{I} = 0$
  ⇒ no current in the relay
- when a fault to earth happens ⇒ no balance in the 3 line currents and out of balance current pass in relay

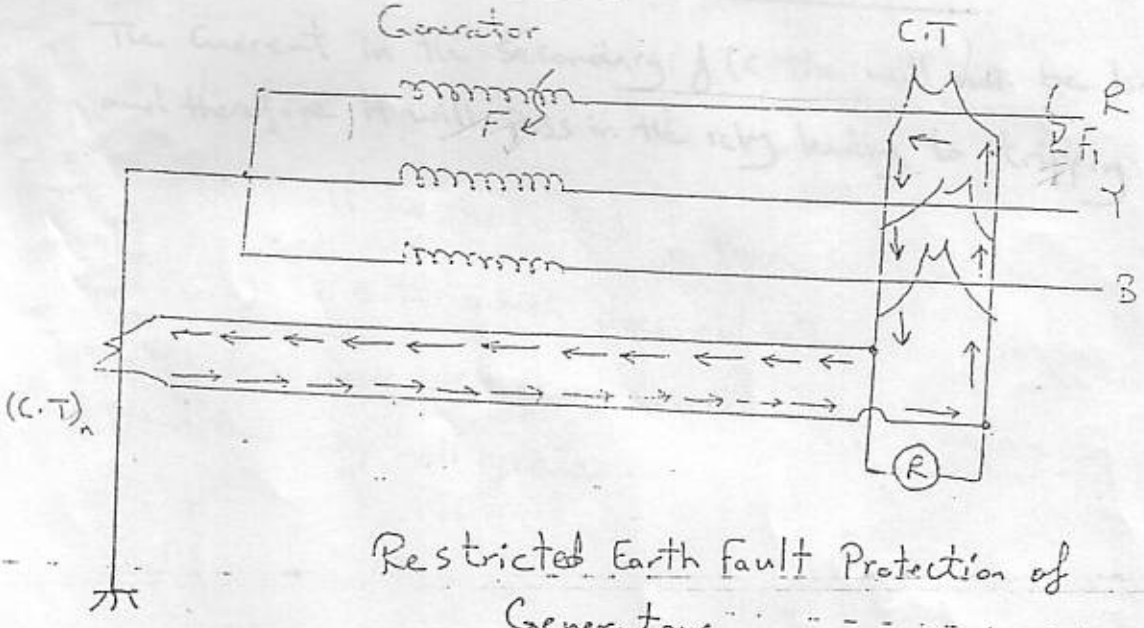
Earth fault Protection of Alternators

(a) No discrimination :—



- If there is a fault in the generator or outside it the relay will operate (No discrimination).

(b) With Discrimination :—



Restricted Earth fault Protection of Generators

- In restricted type 4 C.T's are used one of them connected to the neutral point of the generator.

* In normal conditions :-

The current in the secondaries of C.T's connected to lines will be balanced and no current will pass in the secondary of $(C.T)_n$. Therefore there will be no relay operation.

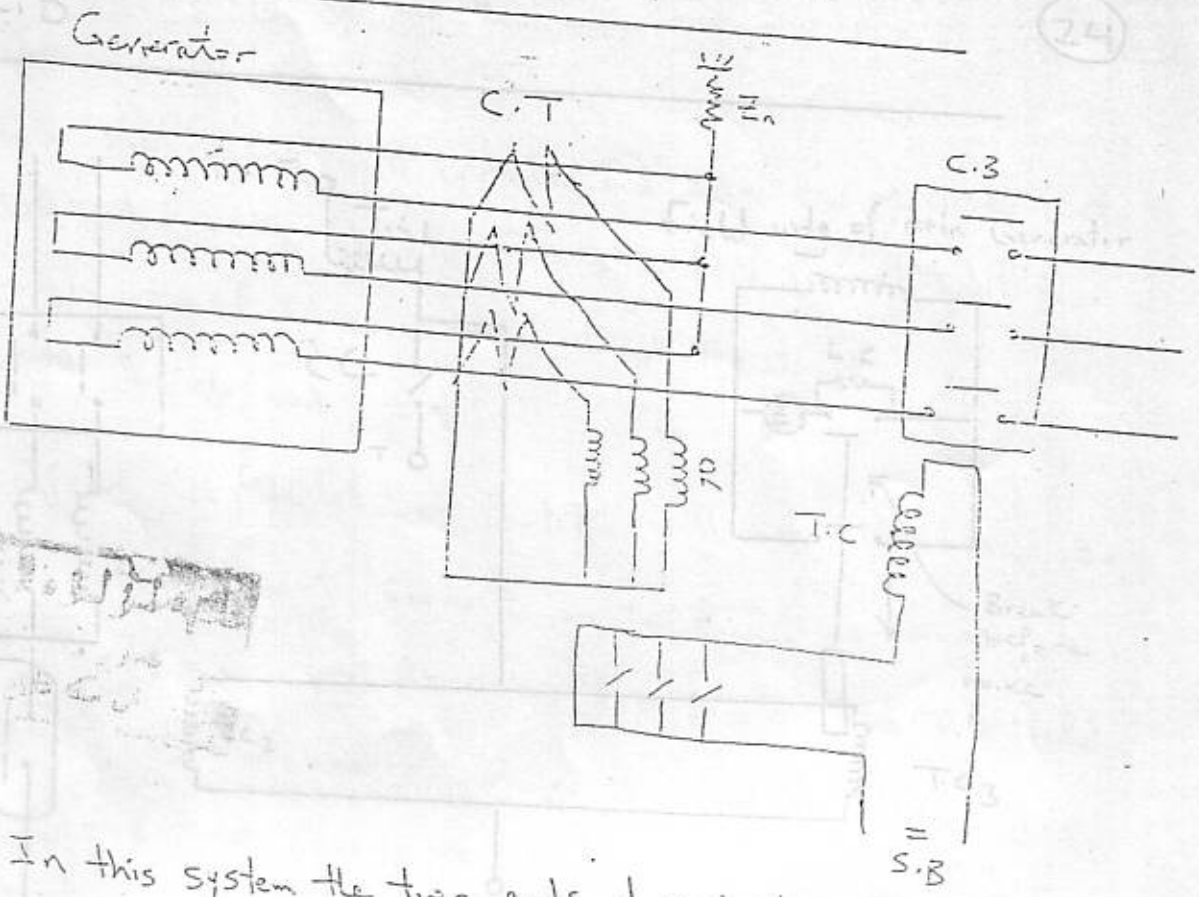
* For a fault outside protected Zone ($\bar{f}_1$) :-

The short circuit current will flow in line "R" and return to the neutral point of the generator, Therefore currents in the secondaries of C.T and $(C.T)_n$ will be balanced and no current will flow in the relay.

* For a fault inside protected Zone (f) :-

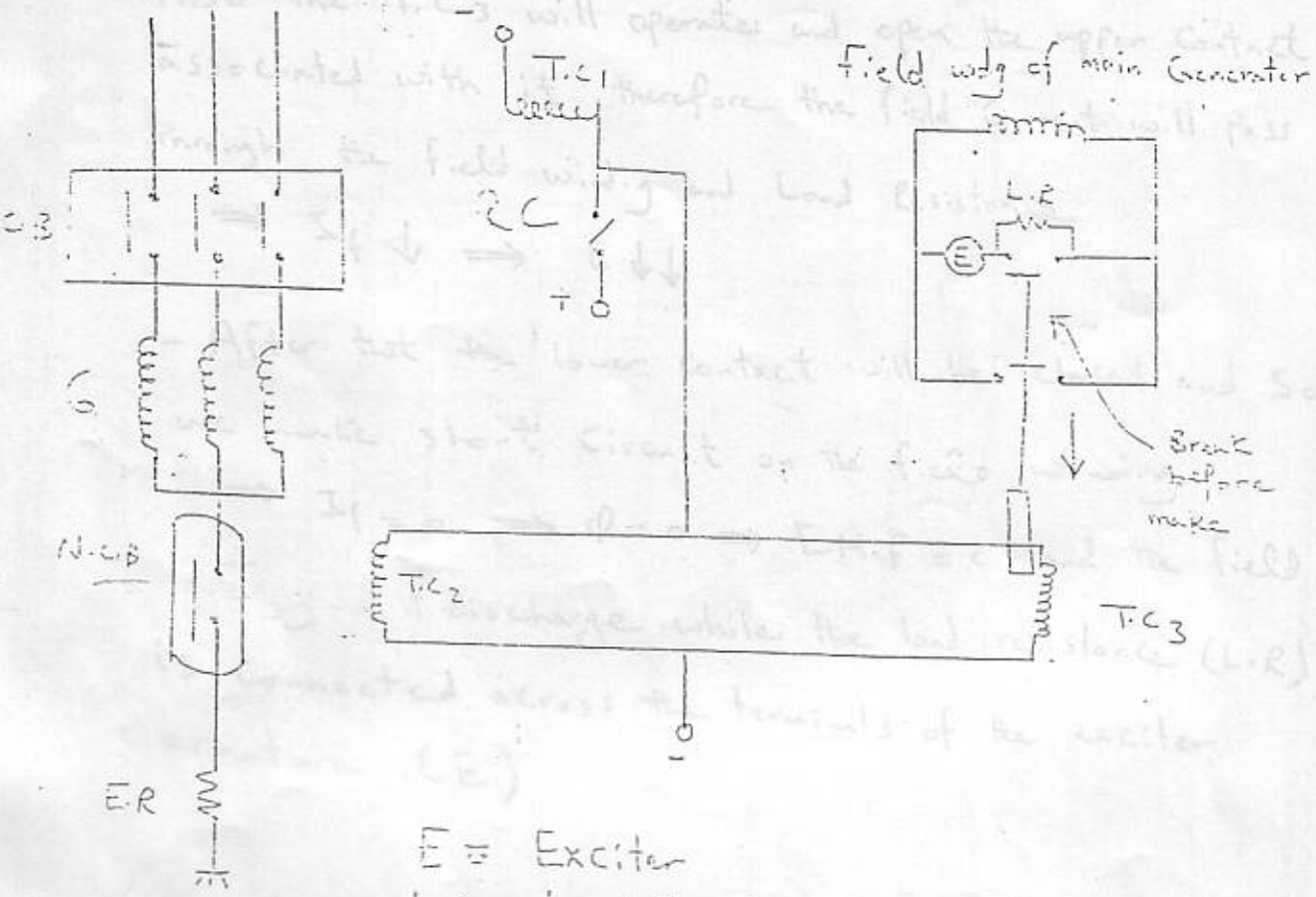
The current in the secondary of $(C.T)_n$ will not be balanced and therefore it will pass in the relay leading to tripping of CB.

Generator Self Balance Protection :-



- In this system the two ends of each phase are taken through a C.T one for each phase.
- Under normal operation ⇒ no current flow in the secondary of the C.T as there is no flux in the core as the current in the start and end points of the winding are equal.
- For a fault in the winding there will be some current flowing to earth which does not pass through the C.T. Therefore there will be a current in the secondary of the C.T and the relay will operate.

Automatic field Suppression and the neutral C.B



E = Exciter
L.R = Load Resistance
N.C.B = Neutral C.B

- When the protection system operates and opened the C.B of the generator in case of a fault, The emf (E) should be suppressed as quickly as possible.
- Although the C.B is opened but e.m.f still generated and will feed the fault by a fault current.
- As $E \propto n\phi$ and speed "n" can't reach zero quickly but ϕ can be reduced as quickly as possible.

- when the relay contacts are closed the T.C1 & T.C2 will operate and the main C.B and N.C.B will open.

- Also the T.C3 will operate and open the upper contact associated with it, therefore the field current will pass through the field winding and Load Resistance

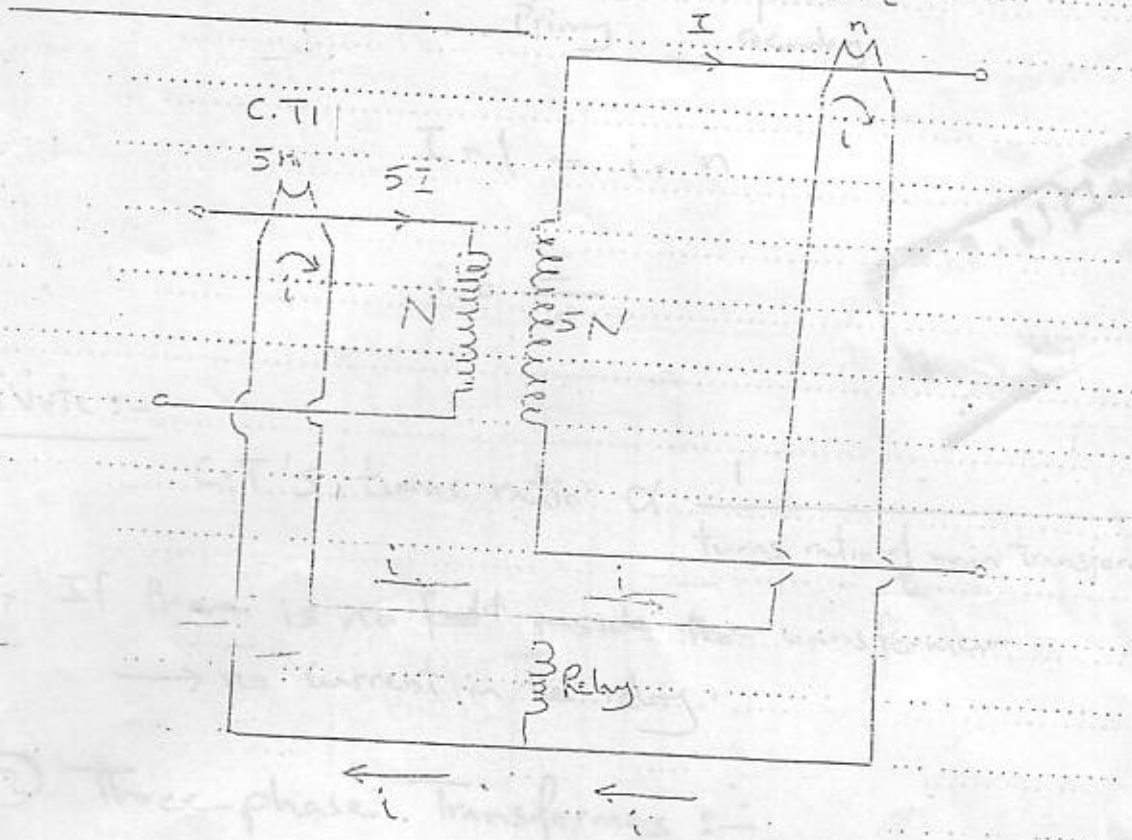
$\Rightarrow I_f \downarrow \Rightarrow E \downarrow\downarrow$

- After that the lower contact will be closed and so we make short circuit on the field winding

$\Rightarrow I_f = 0 \Rightarrow \phi = 0 \Rightarrow E.M.f = 0$ and the field energy will discharge while the load resistance (L,R) is connected across the terminals of the exciter armature (E)

Protection of Transformers

① Single phase Transformers



- Differential Protection is applied for single phase transformers, when the difference in the current magnitudes of primary & secondary windings of the main transformer are connected and taken into account by adjusting the turns ratio of the current transformers.

For C.T1

$$AT|_{primary} = AT|_{secondary}$$

$$5I \cdot 1 = i \cdot 5n$$

$$i = \frac{I}{n}$$

For C.T 2 :

$$AT|_{primary} = AT|_{secondary}$$

$$I_1 = i_2 n$$

$$i = \frac{I_1}{n}$$

Note :-

C.T's turns ratio $\propto \frac{1}{\text{turns ratio of main transformer}}$

* If there is no fault inside the transformer
→ no current in the relay.

② Three-phase Transformers :-

* Power transformers are grouped according to phase displacement between currents in the primary & secondary windings :

Group 1 Δ/Δ , phase shift = 0

Grop 2 Y/Y , phase shift = 180°

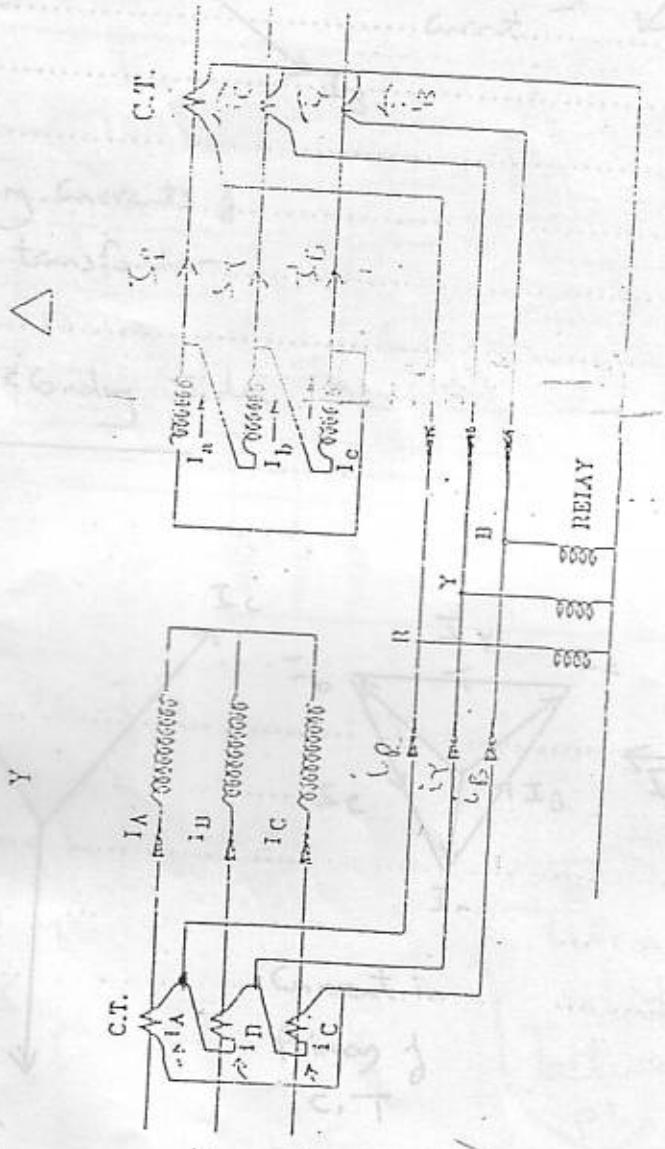
Group 3 Δ/Y , phase shift = -30°

Group 4 Δ/Y , phase shift = +30°

Main Transformer

Y/Δ

Current Transformer Δ/Y to eliminate the phase shift of currents in the secondary of the main transformer.

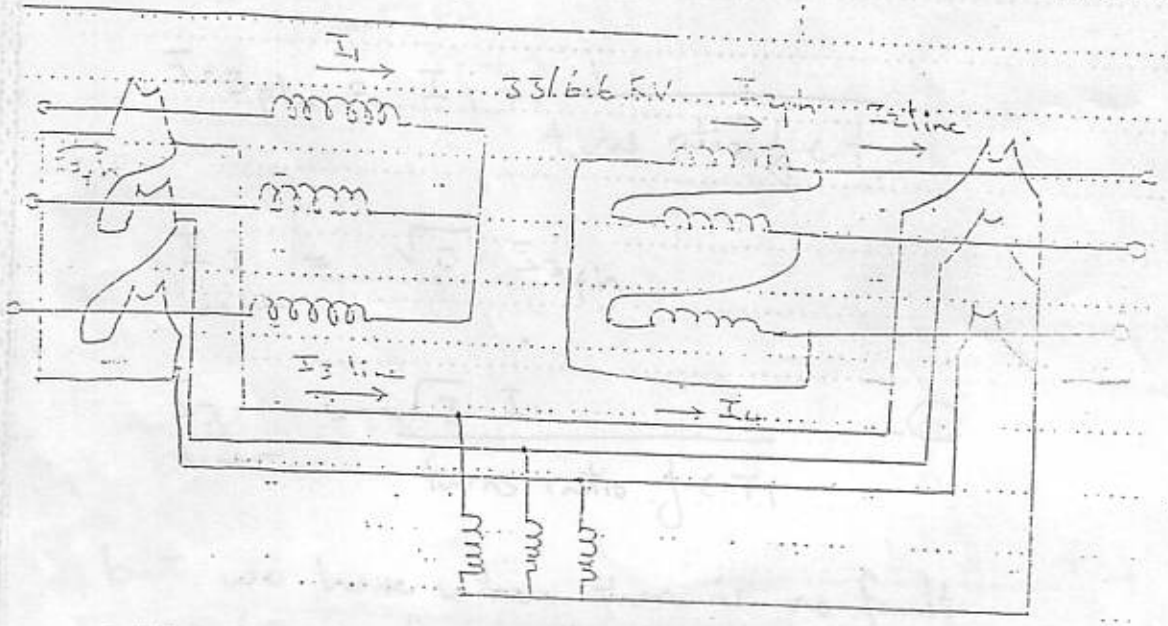


Note:-

The connection of the CT's are opposite to the connection of the main transformer winding to overcome the problem of phase shift.

It can be seen that the currents in the pilot wires are equal in magnitude and in phase opposition, therefore their sum is equal to zero at relay R and no currents will pass in the relay under normal operation.

Problem (5) Sheet (2)



Turns ratio of the main Transformer $= \frac{33/\sqrt{3}}{6.6}$

$$I_{2_{ph}} = I_1 \div \frac{33/\sqrt{3}}{6.6}$$

Turns ratio relation between phase Voltages

$$I_{2_{line}} = I_{2_{ph}} \cdot \sqrt{3}$$

$$\therefore I_{2_{line}} = I_1 \div \frac{33}{6.6 \cdot \sqrt{3}} \cdot \sqrt{3}$$

$$= I_1 \div \frac{33}{6.6}$$

Turns ratio of C.T2 = $\frac{300}{5}$

(7.1)

$\therefore I_4 = I_{2\,line} \times \frac{5}{300}$

$I_4 = I_1 \times \frac{33}{6.6} \times \frac{5}{300}$ — (1)

$I_{3\,ph} = I_1 \times \frac{1}{\text{turns ratio of C.T}_1}$

$I_{3\,line} = \sqrt{3}\, I_{3\,ph}$

$I_{3\,line} = \frac{\sqrt{3}\, I_1}{\text{turns ratio of C.T1}}$ — (2)

but we have when there is no fault (normal operation)

$I_4 = I_{3\,line}$

from (1) & (2)

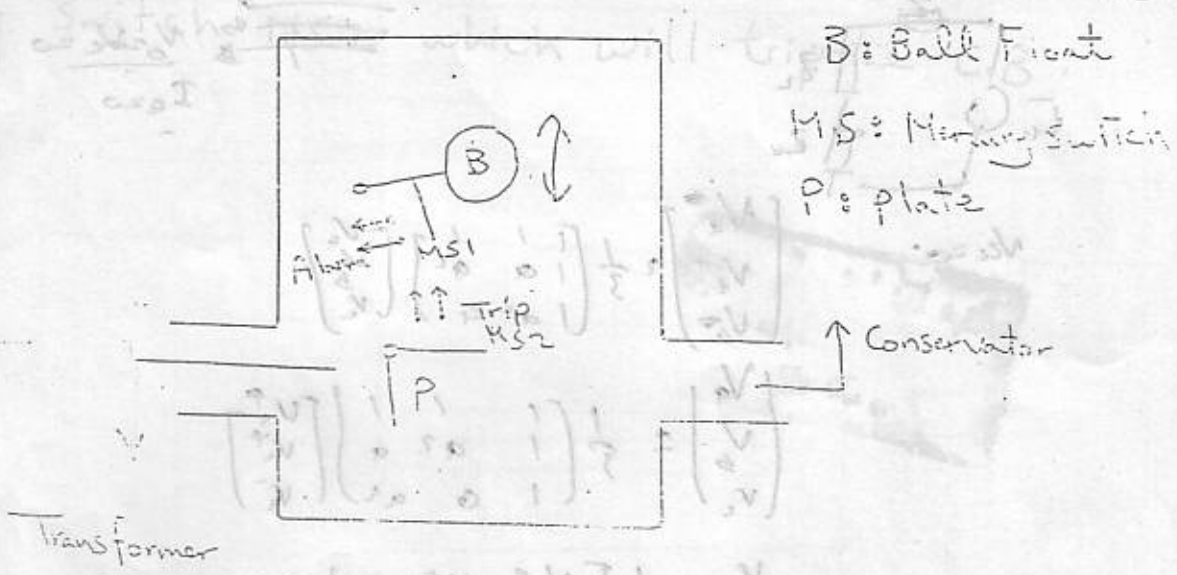
$I_1 \times \frac{33}{6.6} \times \frac{5}{300} = \frac{\sqrt{3}\, I_1}{\text{turns ratio of C.T1}}$

$\therefore$ turns ratio of C.T1 $= \sqrt{3} \times \frac{6.6}{33} \times \frac{300}{5}$

$= \frac{60\sqrt{3}}{5}$

(11)

The Buchholz Relay :-



- This relay is fitted to most oil-filled transformers.
- This relay is fitted in the oil pipe between the transformer tank & oil conservator.
- Under healthy conditions, the relay is full of oil and hence the mercury switch MS1 is open, since the ball float (B) is at its highest position.
- If there is partial failure of the insulation (partial discharge) any where inside the transformer gas will accumulate at the top of the relay and the ball float (B) will drop down causing operation of the alarm mercury switch MS1.

- If there is a short circuit inside the transformer, the explosion will instantly force the oil against the plate (P) and thus closes the mercury switch MSz which will trip the C.B.

ملزمة (7)

Protection (2)

الفرقة الرابعة كهرباء قوى

للاستعلام أتصل على : ٠١٠١٢٤٠٢٦٧

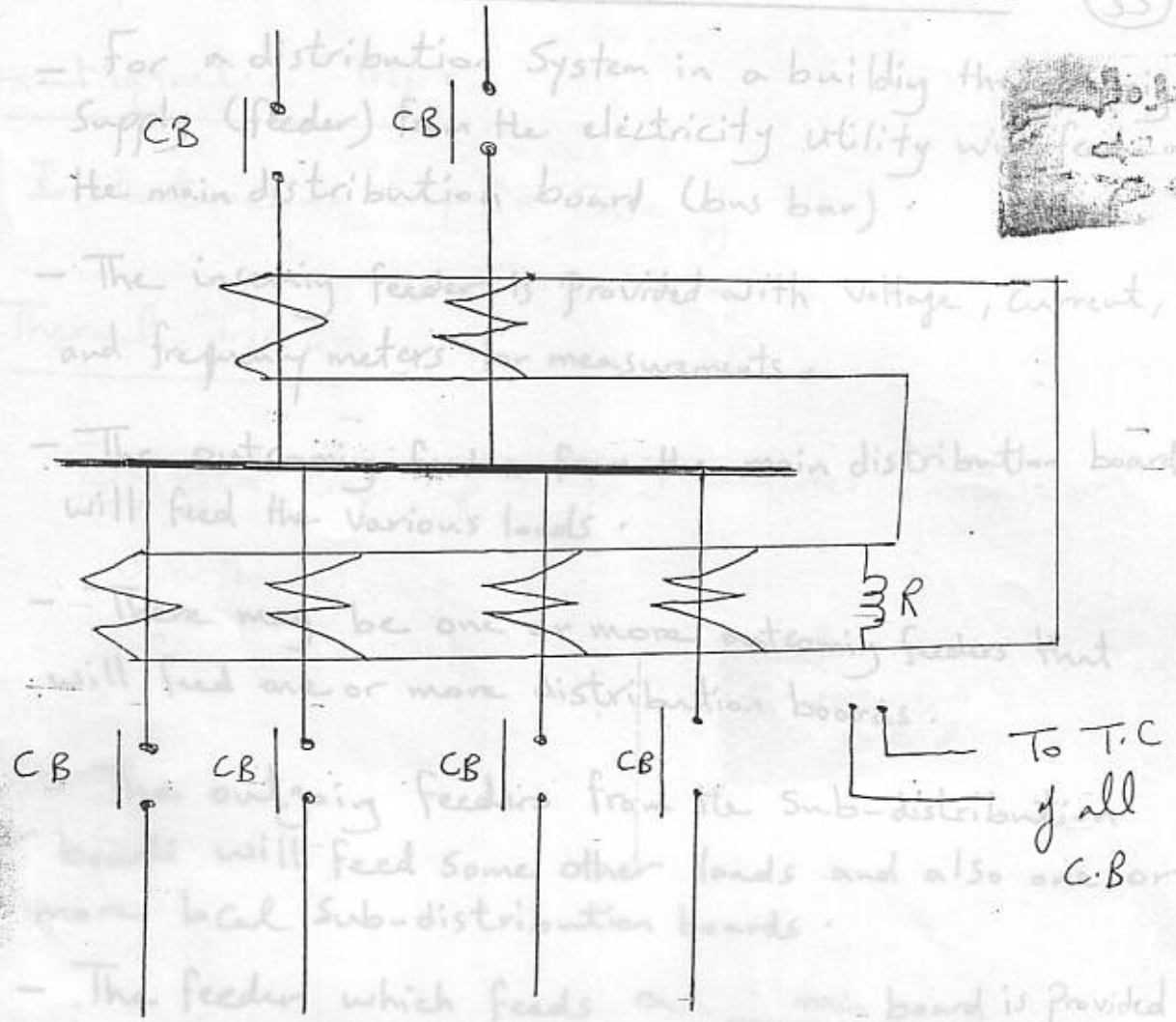
مكتبة لؤلؤة الهندسة

شارع سكة علام – العباسية

كلية الهندسة – جامعة عين شمس

مع تمنياتنا لكم بالنجاح والتوفيق

Protection of Bus Bars



* Bus bars are Protected by differential Protection where current of Incoming and outgoing Paths are Compared.

* If there is any difference in currents indicating there is a fault in bus bar the current will pass in the relay, thus tripping all C.B's

Bus-Bar Switching Arrangements

- For a distribution System in a building the incoming supply (feeder) from the electricity utility will feed the main distribution board (bus bar).
- The incoming feeder is provided with Voltage, current, and frequency meters for measurements.
- The outcoming feeders from the main distribution board will feed the various loads.
- There may be one or more outcoming feeders that will feed one or more distribution boards.
- The outgoing feeders from the Sub-distribution boards will feed some other loads and also one or more local Sub-distribution boards.
- The feeder which feeds a main board is provided with a moulded Case Circuit breaker (m.C.C.B).
- The feeder which feeds various local loads is provided with miniature Circuit breaker (m.C.B).
- The rating of the m.C.C.B is larger than the rating of the m.C.B

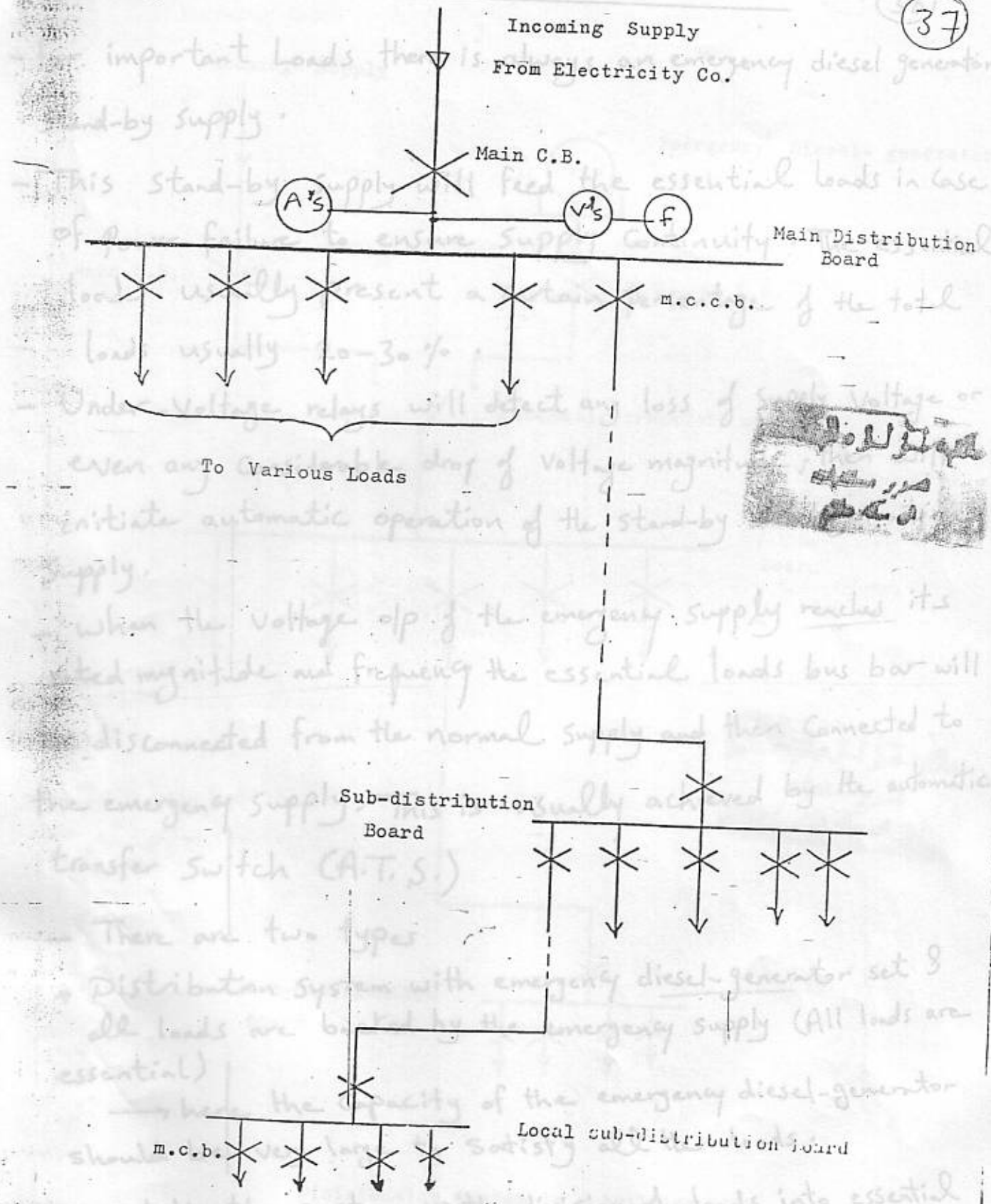
- m.c.c.B is equipped with magnetic trip & thermal trip.

* Magnetic Trip :-

Instantaneous trip in Case of sc.

* Thermal Trip :-

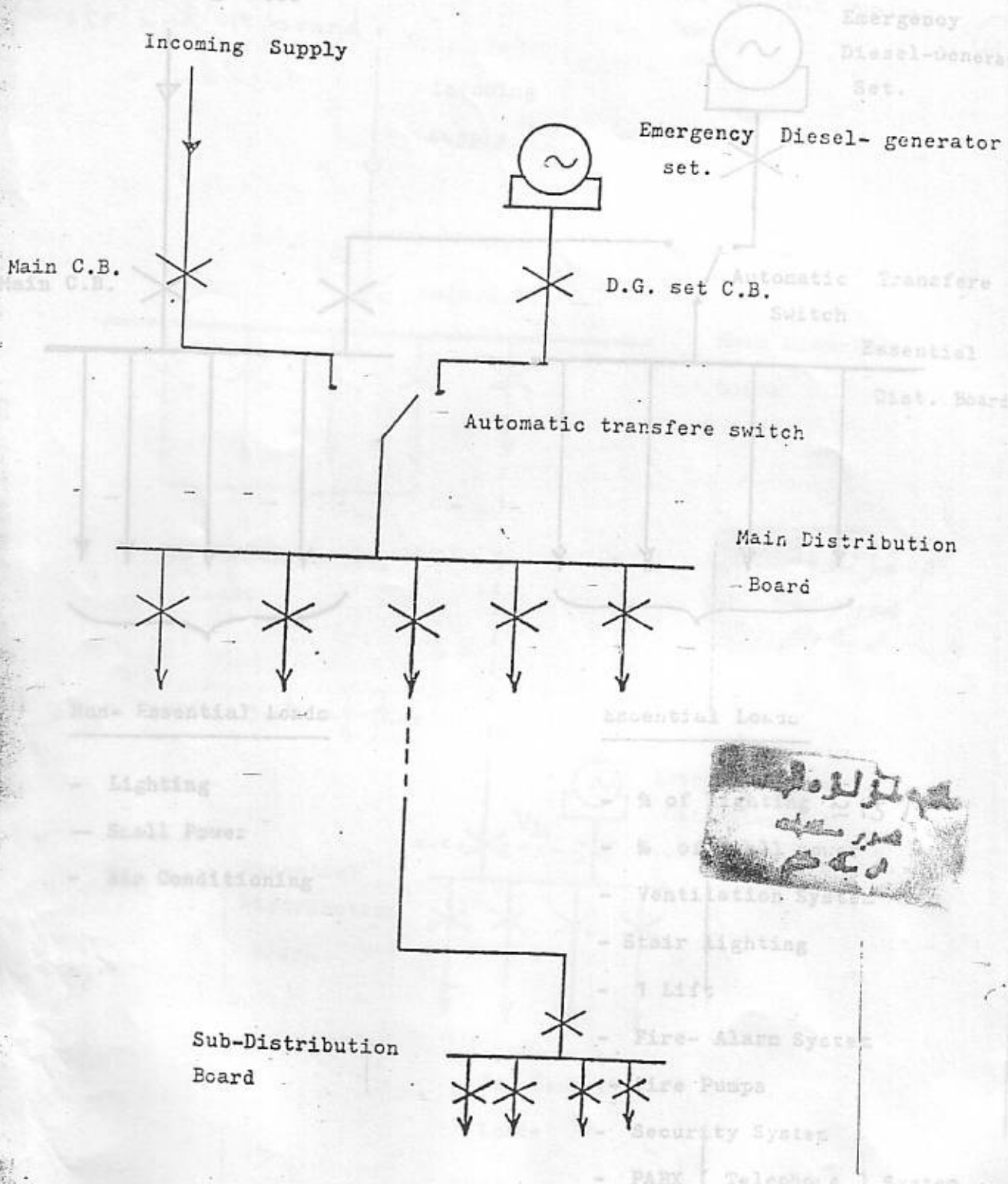
Delayed trip up to few minutes in Case of overload.



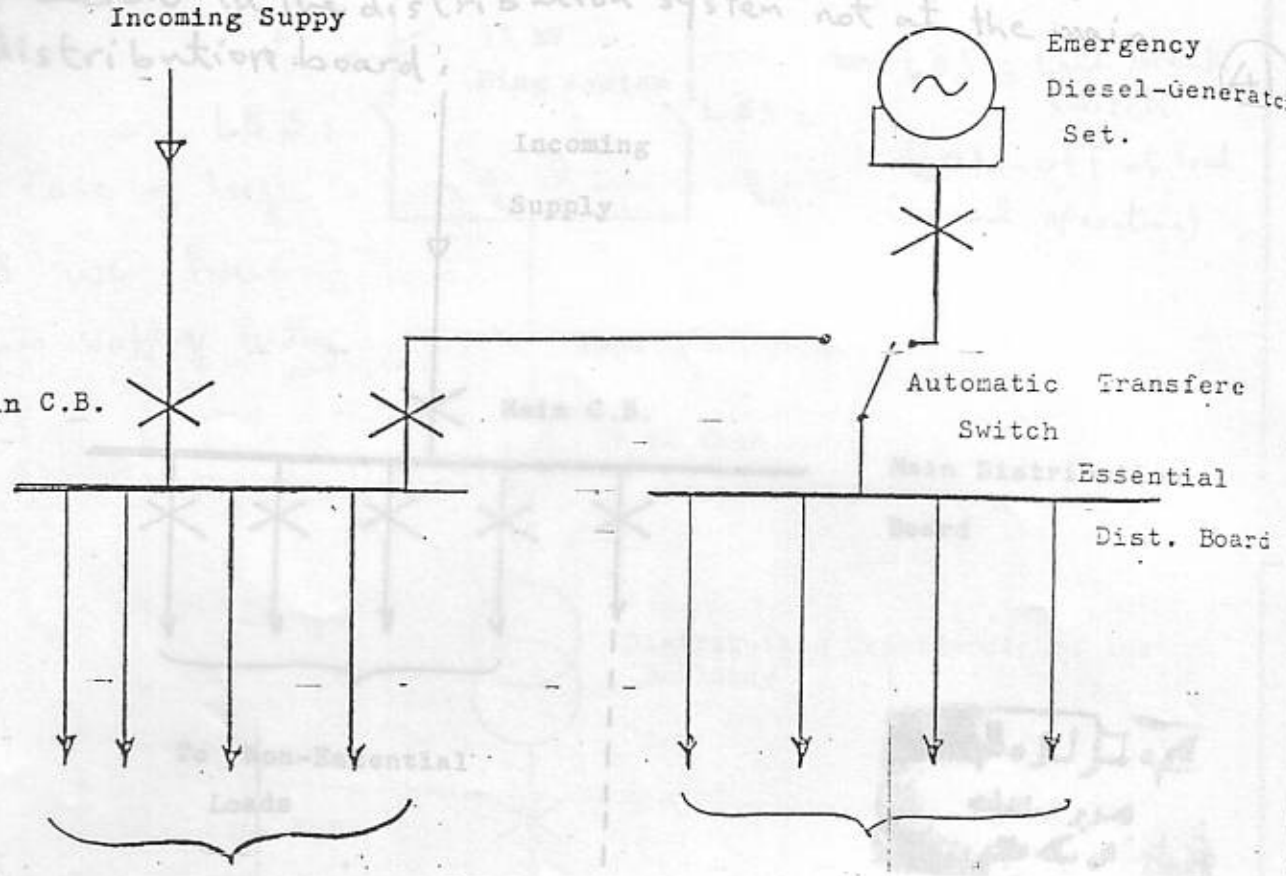
Distribution System in a building, showing down-stream breakers. Discrimination should be ensured.

Essential Load Switching Arrangement

- For important Loads there is always an emergency diesel generator stand-by supply.
- This stand-by supply will feed the essential loads in case of power failure to ensure supply continuity. The essential loads usually present a certain percentage of the total loads usually 20-30 %.
- Under-Voltage relays will detect any loss of supply voltage or even any considerable drop of voltage magnitude, then will initiate automatic operation of the stand-by diesel generator supply.
- when the voltage o/p of the emergency supply reaches its rated magnitude and frequency the essential loads bus bar will be disconnected from the normal supply and then connected to the emergency supply. This is usually achieved by the automatic transfer switch (A.T.S.)
- There are two types
  * Distribution system with emergency diesel-generator set & all loads are backed by the emergency supply (All loads are essential)
    → here the capacity of the emergency diesel-generator should be very large to satisfy all the loads.
  * Distribution system with division of loads into essential and non-essential loads at the main distribution board.



Distribution System in a building with emergency diesel-generator set. All loads are backed by the emergency supply.



Non- Essential Loads

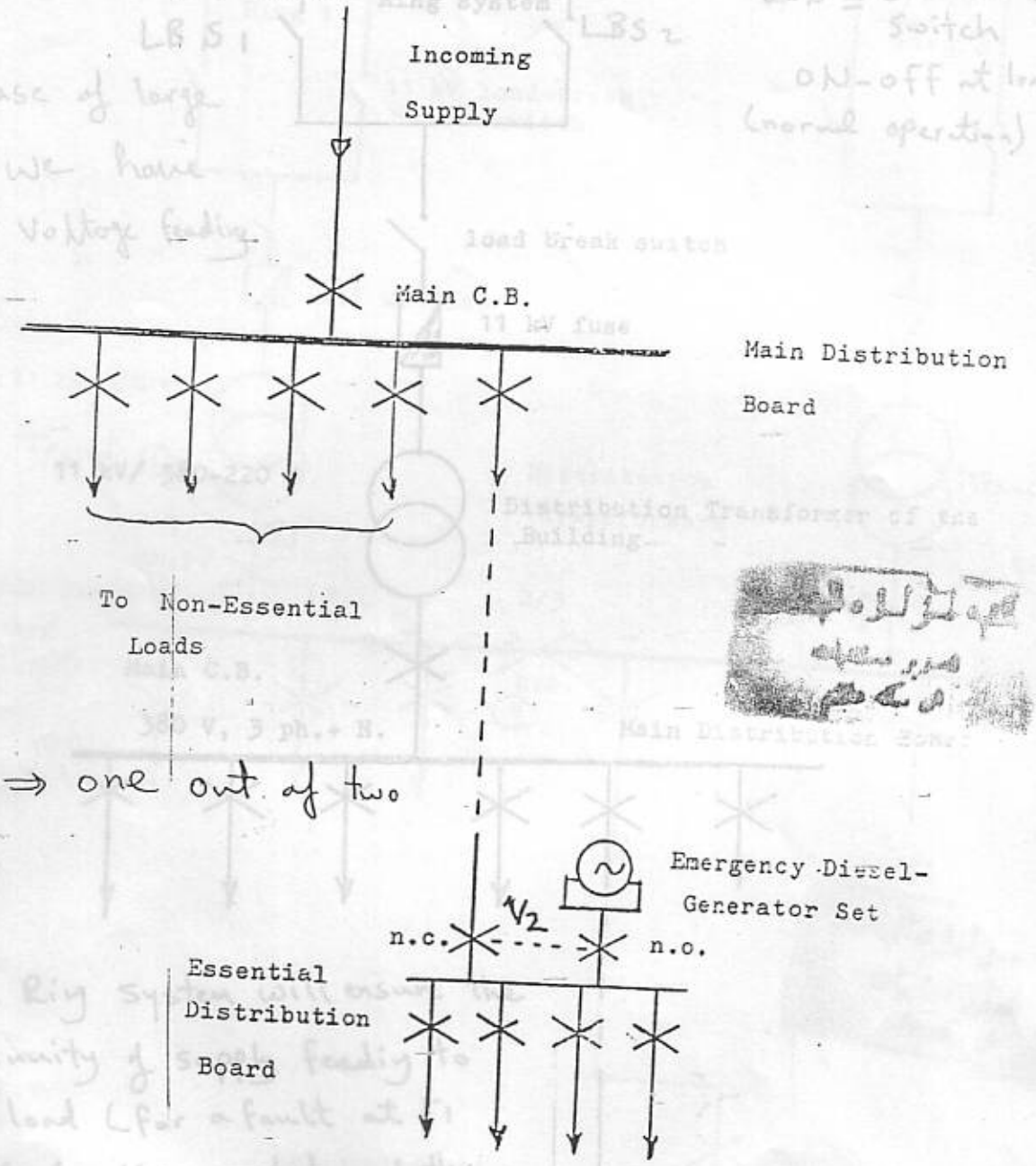
- Lighting
- Small Power
- Air Conditioning

Essential Loads

- % of lighting ≈ 15 %
- % of small power
- Ventilation System
- Stair lighting
- 1 Lift
- Fire- Alarm System
- Fire Pumps
- Security System
- PABX (Telephone) System
- Computer System

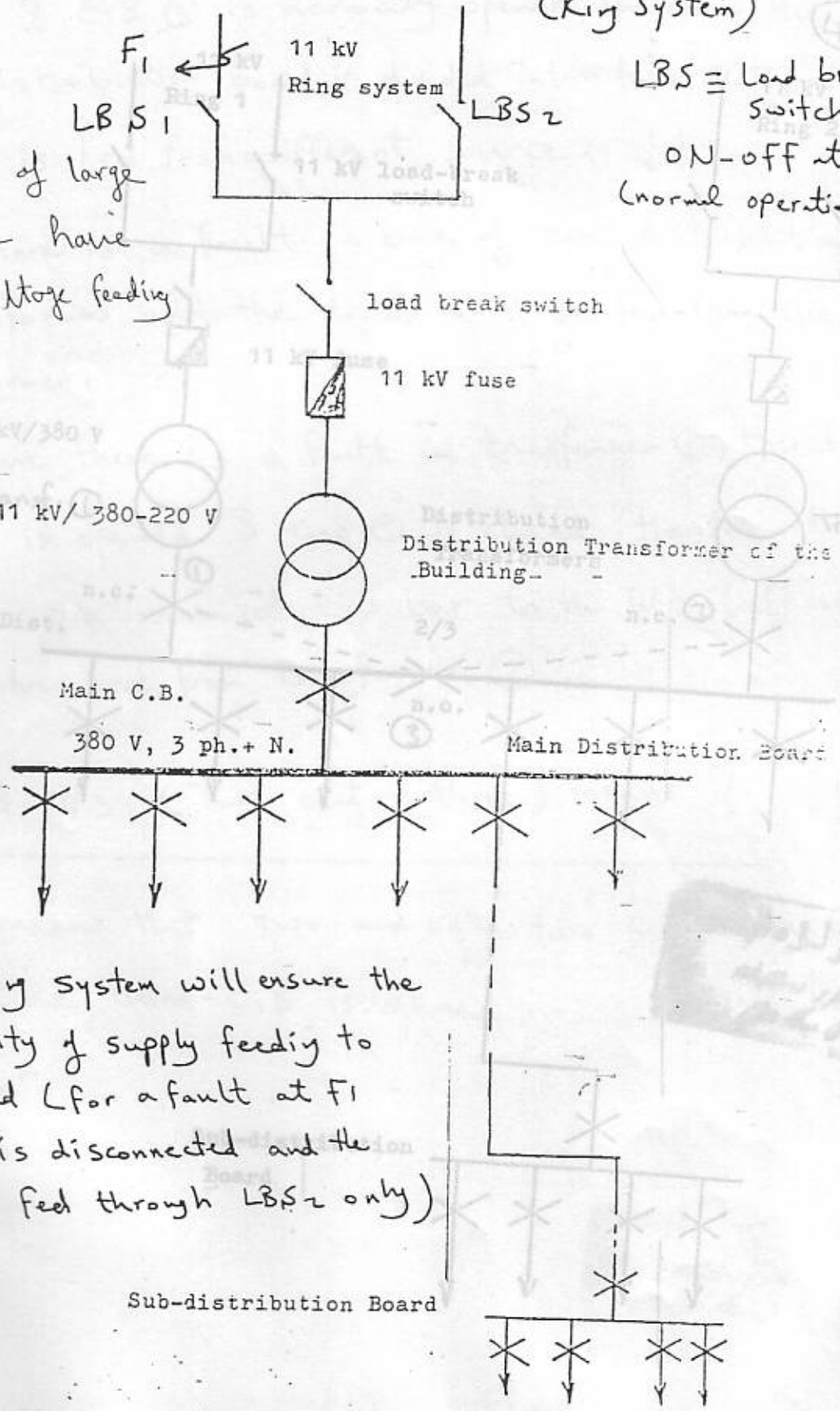
Division of loads in a building into Essential & Non-Essential Loads. Essential loads will include CRITICAL loads.

Here the essential loads are at different locations in the distribution system not at the main distribution board.



Distribution System in a building with Main Distribution Board & Essential Distribution Board at different Locations.

Distribution system with supply at 11 KV (Ring System)



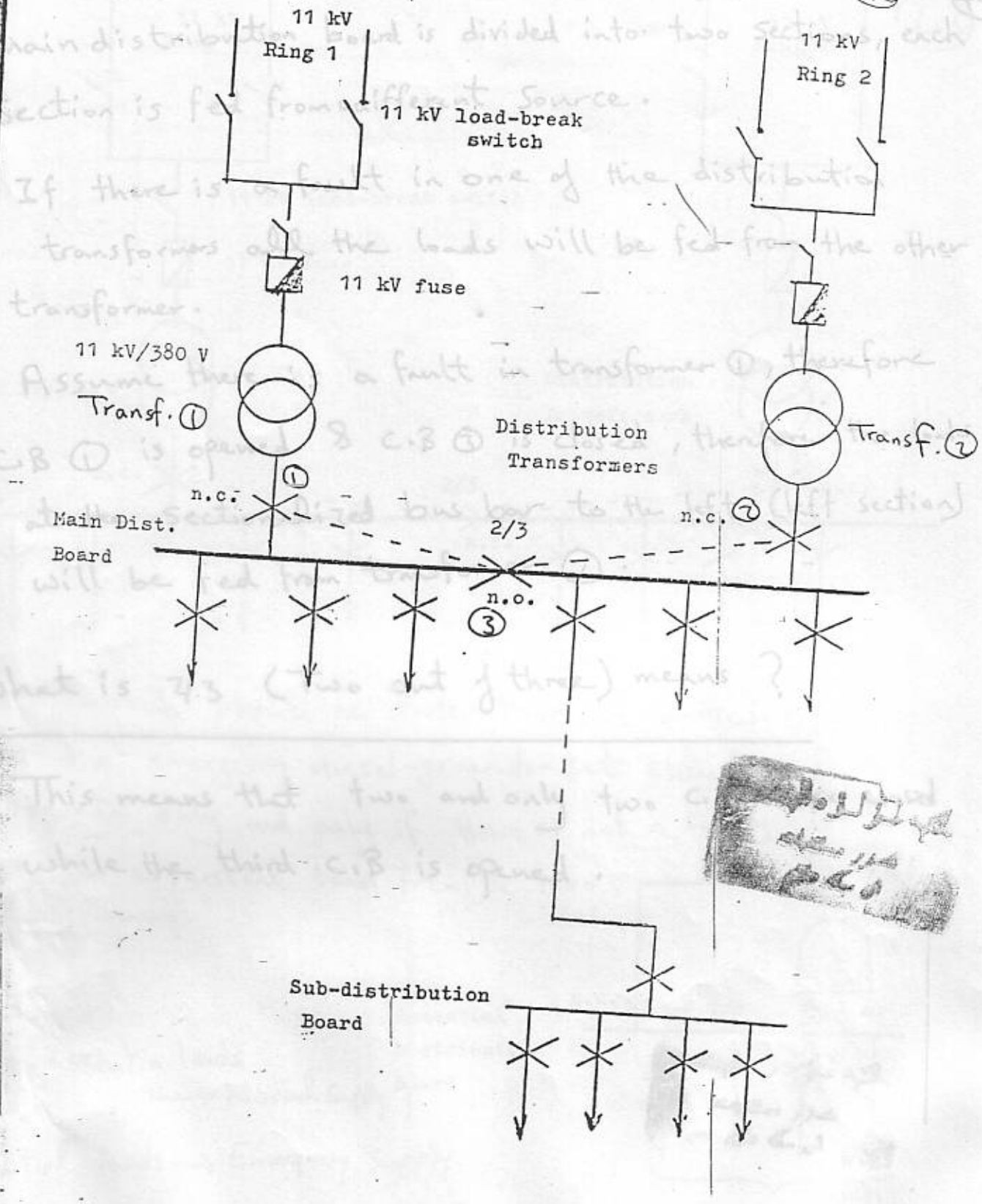
LBS ≡ Load break switch
ON-off at load (normal operation)

In case of large loads we have medium voltage feeding

The Ring system will ensure the continuity of supply feeding to the load (for a fault at F1 LBS1 is disconnected and the load is fed through LBS2 only)

Distribution System in a building. Supply to building at 11 KV

Distribution system with two different Sources :-



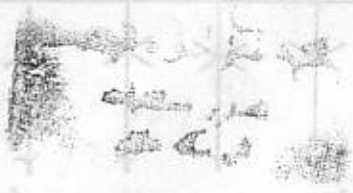
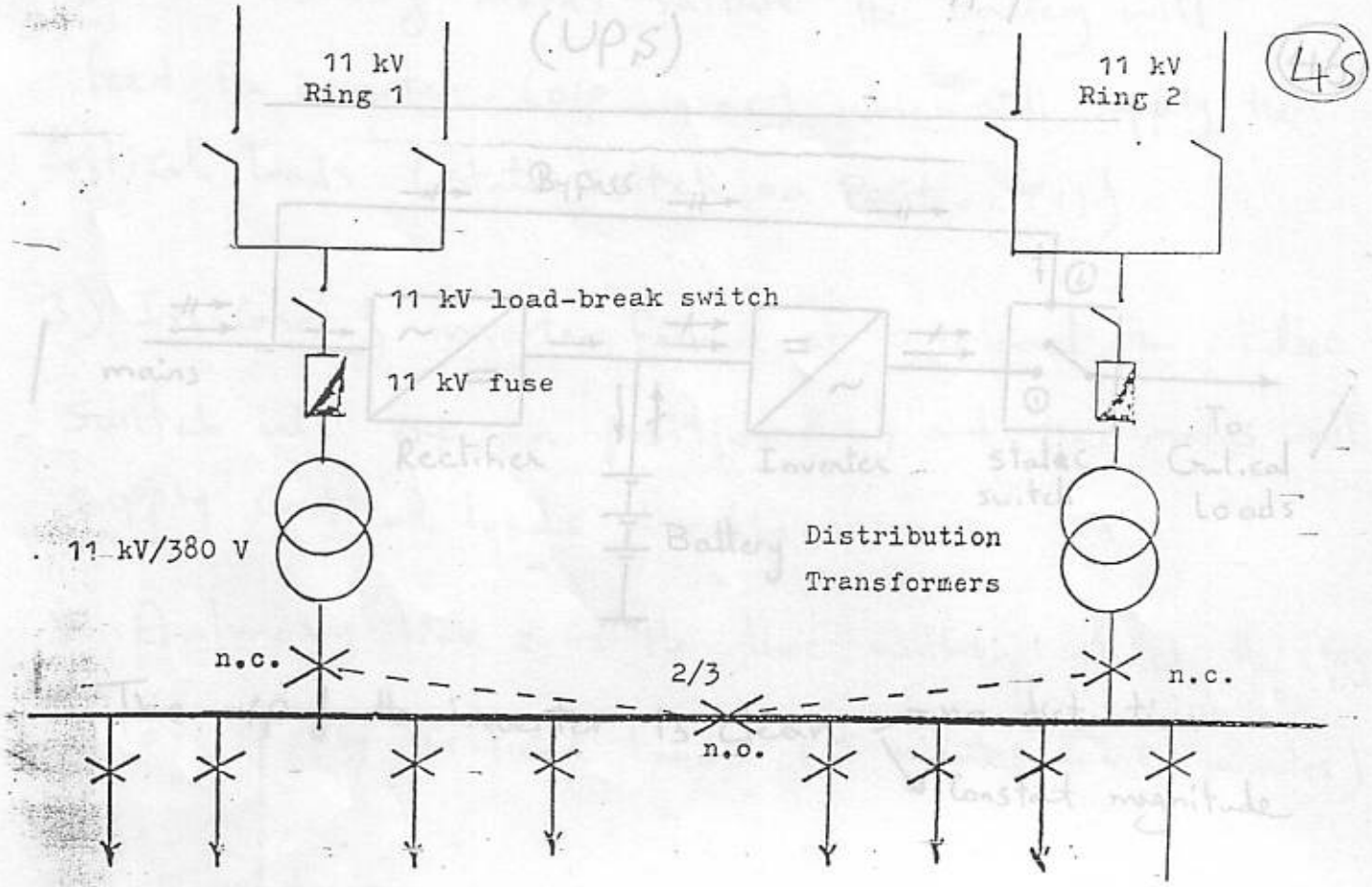
Supply to building from two different sources

- At normal operation C.B ① & ② are normally closed & C.B ③ is normally opened, therefore the main distribution board is divided into two sections, each section is fed from a different source.

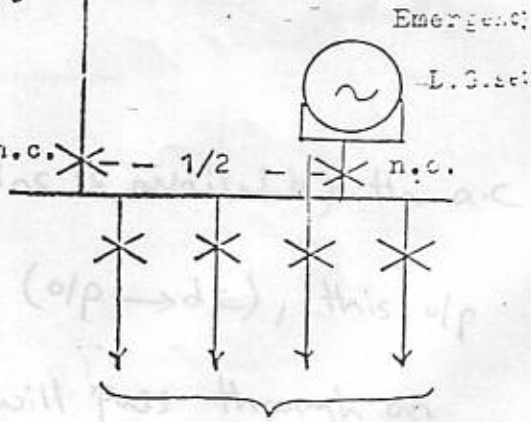
- If there is a fault in one of the distribution transformers all the loads will be fed from the other transformer.

- Assume there is a fault in transformer ①, therefore C.B ① is opened & C.B ③ is closed, therefore the loads at the sectionalized bus bar to the left (left section) will be fed from transformer ②.

What is 2/3 (Two out of three) means ?

This means that two and only two C.B's are closed while the third C.B is opened.



* 2/3 switch should be faster than 1/2 switch as the emergency diesel-generator set should operate only and only if there is not a supply to the essential load from the two transformers.



Essential Distribution Board

Essential Loads

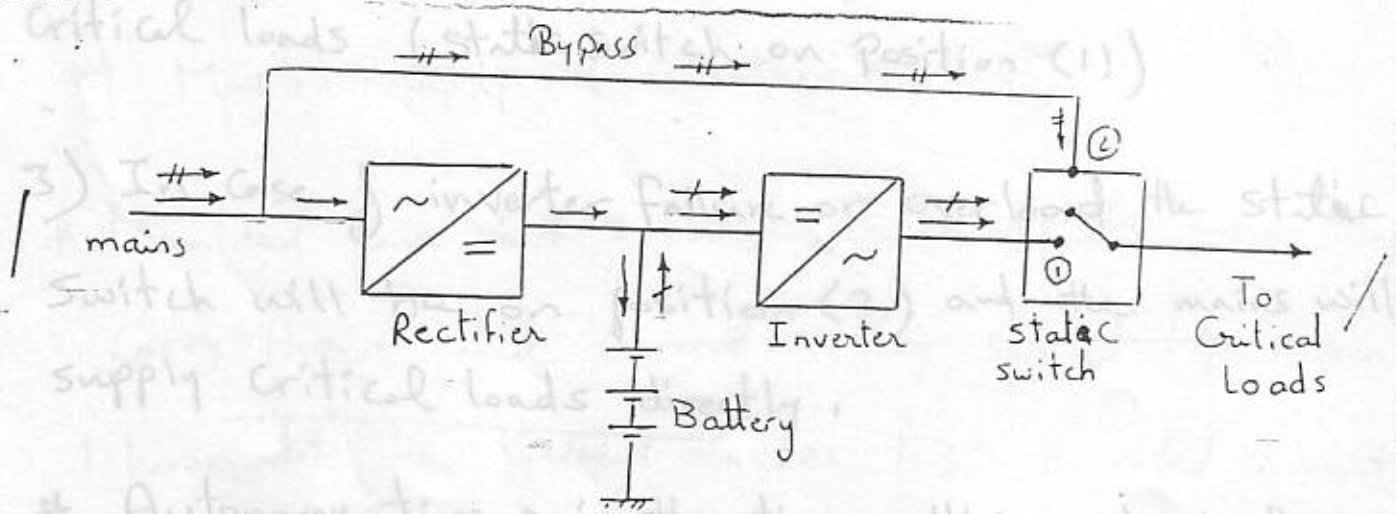
Non-essential loads → Normal Supply

Essential loads → Emergency Supply

Critical loads → Uninterruptable Power Supply (UPS)

Supply to building from two different sources, with emergency supply to essential loads only.

Uniterruptable Power Supply (UPS)



- The o/p of the inverter is clean → no distortion
  → Constant magnitude

→ Power flow when mains is available.

⇢ Power flow in case of mains failure.

⇢⇢ Power flow in case of inverter failure or overload

operation :-

1) In normal case (when the mains is available) the a.c supply will pass through a rectifier (o/p → dc), this o/p will charge the battery and also will pass through an inverter (o/p → ac) which will supply the critical loads (state switch on position (1))

2) In case of mains failure the battery will feed the inverter (o/p → ac) which will supply the critical loads (static switch on position (1))

3) In case of inverter failure or overload the static switch will be on position (2) and the mains will supply critical loads directly.

* Autonomy time : is the time within which the UPS can supply critical loads (5 minutes → 30 minutes)

* Ratings of UPS 200 VA → 500 KVA
500 VA

As the rating ↑ → price ↑

d/c's of Circuit Breakers

Types of C.B's

Types of C.B :

1) minature circuit breaker (M.C.B)
2) moulded case circuit breaker (m.c.c.B)
3) Large C.B (SF6, Air Blast, oil)

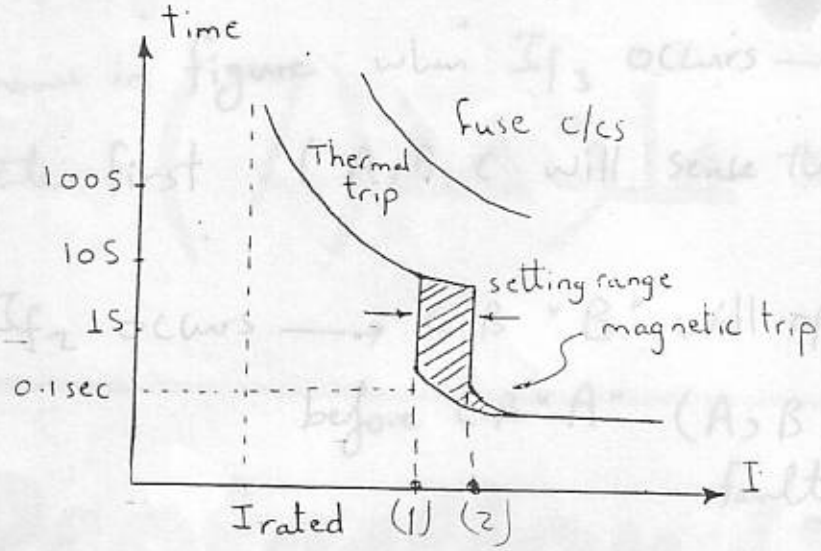
* C.B is usually equipped with
  1) Thermal trip (inverse time c/cs)
  2) Magnetic trip (instantaneous trip)

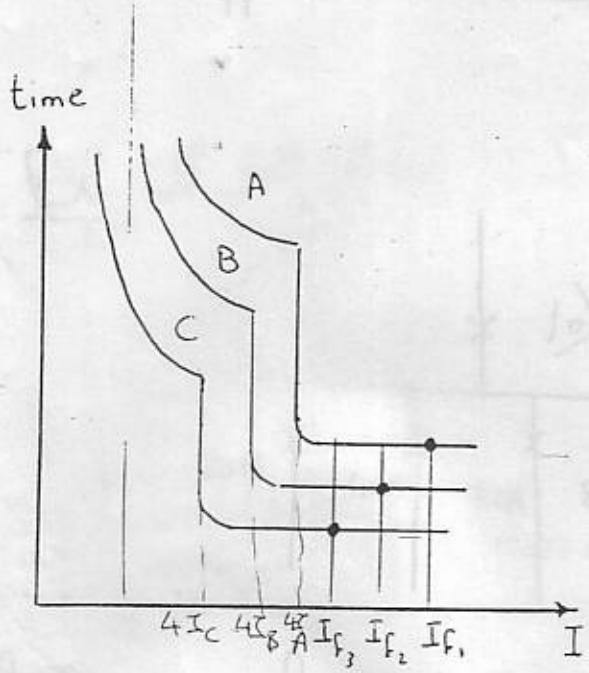
* Moulded Case C.B's should not operate when they carry their rated current. They should trip within 1 hour if the current reaches 1.35 the rated current.

* Types of C.B's according to I.E.E (Institute of Electrical Engineers)

1) Type I : instantaneous tripping between 2.7-4 I_{rated}
   (used for ordinary loads)
2) type II : instantaneous tripping between 4-7 I_{rated}
   (used when there is a considerable inrush current i.e : motor starting)
3) type III : instantaneous tripping between 7-10 I_{rated}
   (used when Feeding banks of lighting Circuits, motors, transformers)
4) type IV : instantaneous tripping more that 10 I_{rated}
   (used when feeding welding machines, X-ray equipment)

To





In order to ensure proper discrimination between C.B's the c/cs of each C.B should be taken into account when a fault occurs on a sub-circuit, the breaker feeding this sub-circuit should trip before the main C.B.

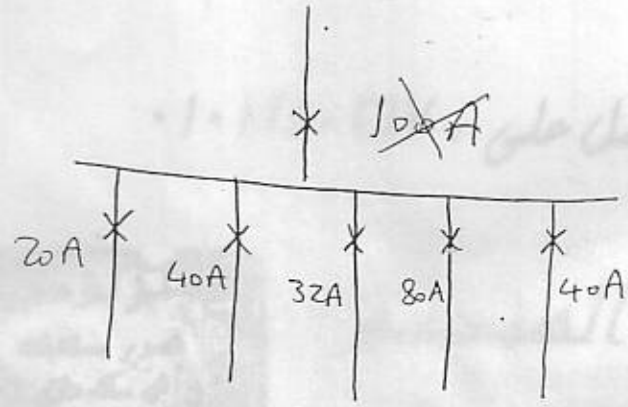
Ex:-

As shown in figure when If_3 occurs → C.B "C" will operate first (A, B, C will sense the fault).

* when If_2 occurs → C.B "B" will operate first before C.B "A" (A, B only sense the fault).

* when If_1 occurs → C.B "A" will only operate (A only sense the fault).

Ex



As a general guide the rating of the main incomig C.B in any distribution board, should be at least twice the rating of any outgoing breaker in that distribution board

Rating of CB's 10A, 16A, 20A, 26A, 32A, 40A, 63A
80A, 100A, 125A, 160A, 200A, 250A

ملزمة (8) ٥ ب.ع

Protection (2)

الفرقة الرابعة كهرباء قوى

للاستعلام أتصل على : 0101240267

مكتبة لؤلؤة الهندسة

شارع سكة علام – العباسية

كلية الهندسة – جامعة عين شمس

مع تمنياتنا لكم بالنجاح والتوفيق

Over-voltage Protection and Insulation Coordination

V0

Difference between Insulation design of H.V substations & O.H.T.L

1- Stations normally contain transformers & other equipment with solid insulating materials (non self restoring insulation) on the other hand O.H.T.L is self restoring insulation (basic insulation is air).

Note :-

Self resturing insulation is the insulation which can retain its c/c's after flashover or breakdown.

2- Stations have important functions in the power System, therefore flashover or breakdown of its insulation should be kept to a minimum.

Insulation Coordination :-

Is a correlation of insulation of equipment with the c/c's of protective devices such that the insulation is protected from over voltages.

- To achieve this goal the equipment in stations are protected by means of shunt-connected Protective devices.

- The Basic Insulation level (BIL) of the equipment have to be above the protective level by a suitable margin.

By this method the protective device will spark over at a voltage less than the insulation withstand voltage of the equipment.

For UHV systems Switching impulse insulation level (SIL) is assigned

Overvoltage Protective Devices :-

As mentioned before to avoid flashover or breakdown of any insulation in a substation or a power station the c/cs of the protective device must lie below the withstand level of the equipment to be protected

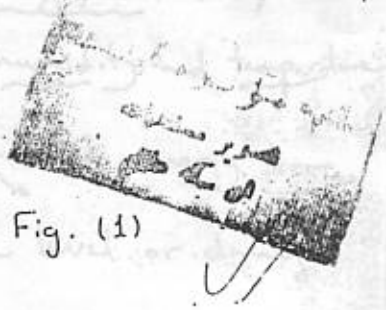
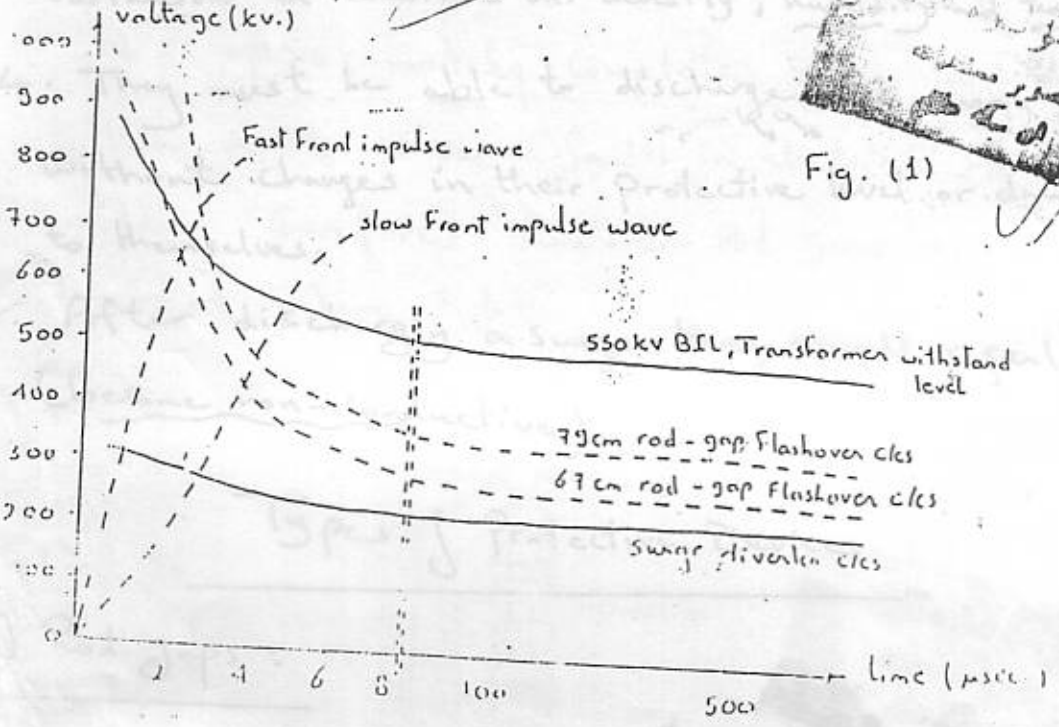


Fig. (1)



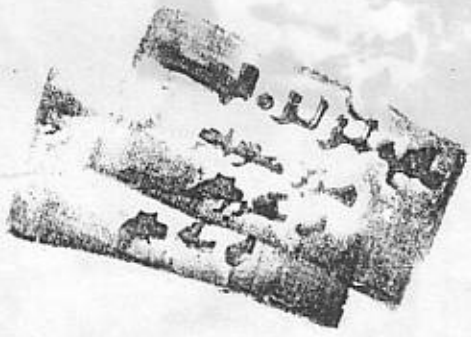
Transformer Protection by rod-gaps and Surge diverters Volt/time c/cs

Requirements of ideal shunt connected Protective devices :-

1. Ideal Protective devices must not spark over under temporary voltages.
2. The surge diverter c/c should lie below the withstand level of the Protected insulation in any time region in which protection is needed.
3. The margin between the two curves must be Suitable to allow for the effect of distance, Variations in relative air density, humidity and temperature.
4. They must be able to discharge high energy surges without changes in their protective level or damage to themselves.
5. After discharging a surge they should regal (become non-conductive).

Types of Protective Devices

1) Rod gaps :



Advantages

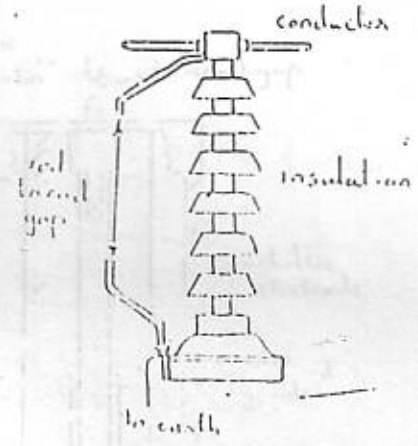
1. Simple
2. cheap

Disadvantages :-

1. The B.D c/c's will differ due to changes in atmospheric conditions, or electrode Polarity

2. The c/c's of rod gap bends up sharply for fast front wave (. This may cause B.D of insulation at small times as the fast front impulse wave will intersect the c/c's of the equipment withstand c/c's before rod gap c/c's).

3. Under operating conditions → (BD of rod gap) → Collapse of voltage to almost zero Voltage occurs, this approximately complete SC which is one of the most severe faults in electrical Power System. Therefore, Rod-to-Rod gaps may be used in areas where lightning surges are of low activity level.



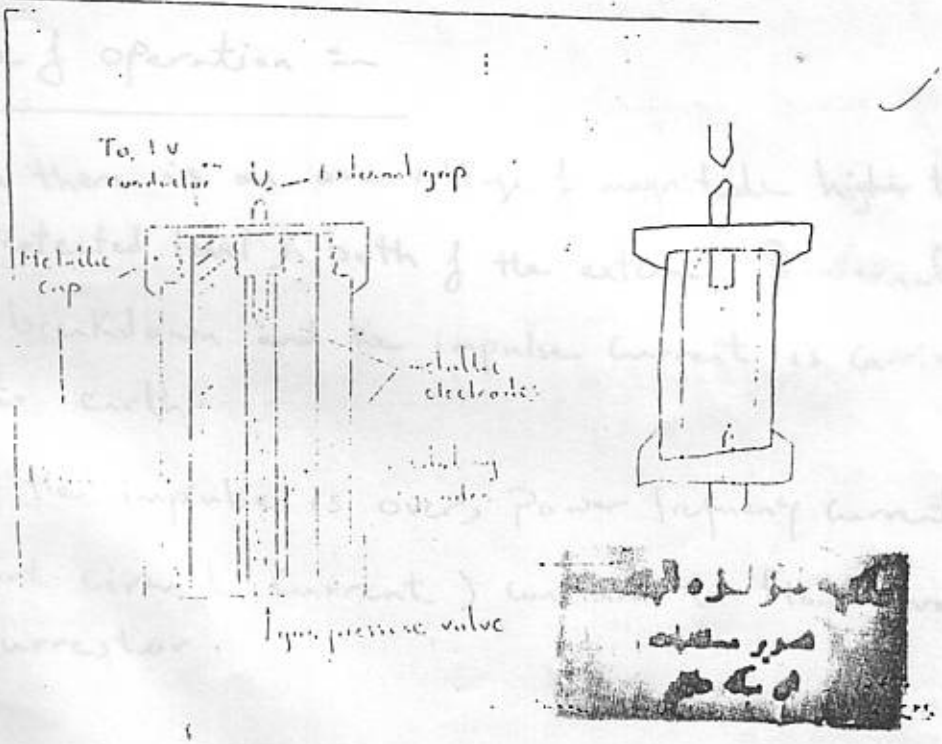
2) Surge diverters (Surge arrestor)

To overcome the disadvantages of rod gaps, usage of lightning arrestors (surge diverters) which extinguish the arc produced between electrodes in a short time which is less than the time of action of relay operation.

Types of Surge diverters

- Expulsion tube: used mainly for O.H.T.L
- Auto Valve Surge arrestors used for Protection of Substation insulation

1 Expulsion Tube Surge arrestors :-



Construction :-

+ The main tube consists of an insulating tube having an electrode at each end and a discharge vent at the lower end. The length of the tube is designed such that the spark over occurs across the gap between the two electrodes within the tube.

+ The tube is also installed such that there is an external series gap between the line conductor and the tube above metallic end. This arrangement prevent continuous application of the system voltage to the tube thereby prevent leakage and corona. Therefore, the external gap increases life performance of the expulsion tube surge arrestor.

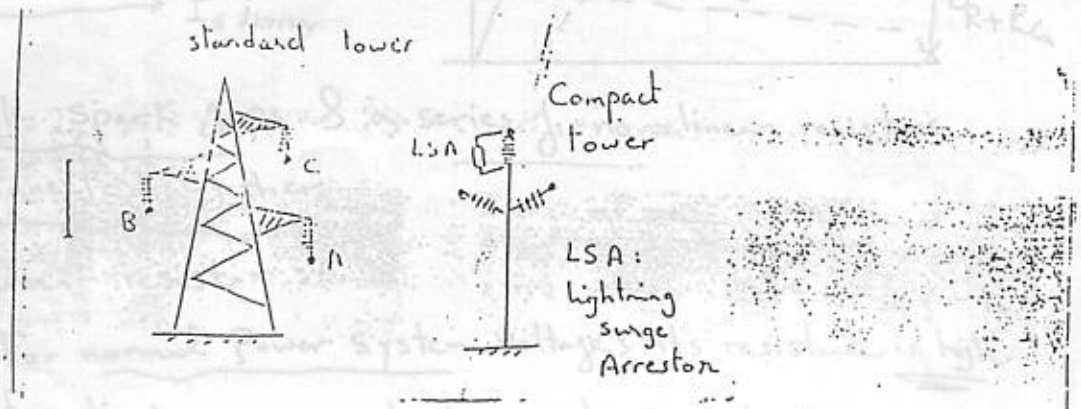
Sequence of operation :-

(1) When there is an over voltage of magnitude higher than the protected level, both of the external & internal gap's breakdown and the impulse current is carried away to earth.

(2) After the impulse is over, Power frequency current (short circuit current) continue to flow through the arrestor.

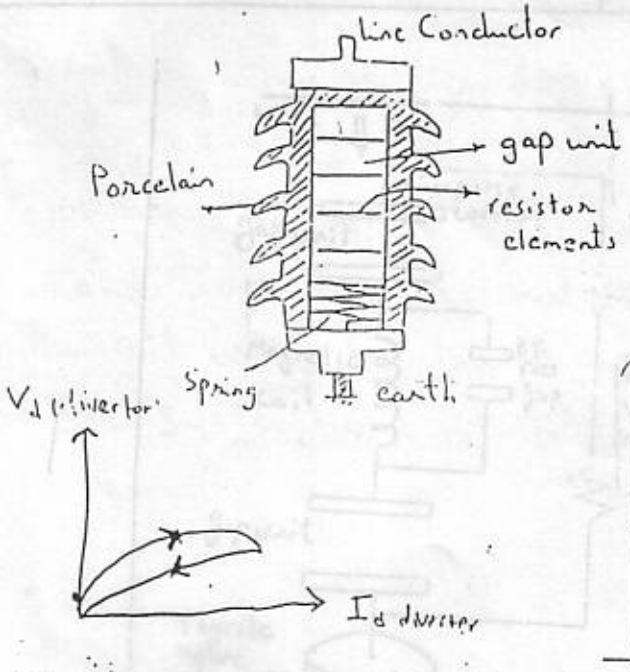
③ Due to high temperature, gas pressure in the tube increases up to a value of few tens of atmospheric pressure. At a certain pressure the Pressure valve opens & the gas flows towards the opened vent. This gas will flow and help in extinguishing the arc within a reasonable time duration Period.

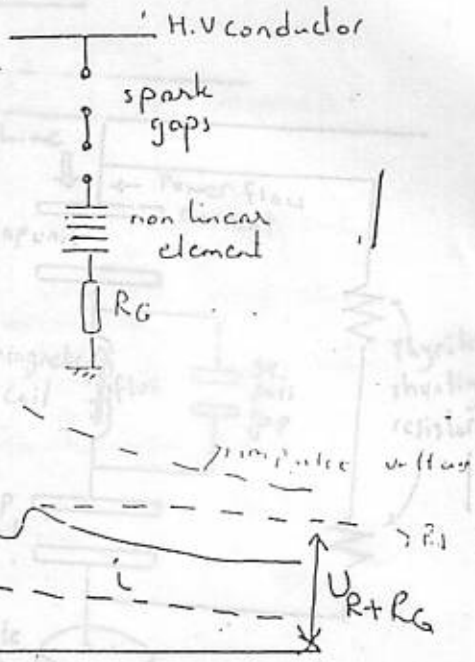
Compact towers using Surge arrestors :-



- Surge arrestors can be used in certain areas to decrease the insulation level of tower & also to decrease the flashover rate.
- By use of LSA the dimension of the insulation string will be decreased and we will reach what is called Compact tower.
- Compact towers reduce right of way.
- We can use towers without an earth wire.

2] Auto-Valve arrestor Type :-



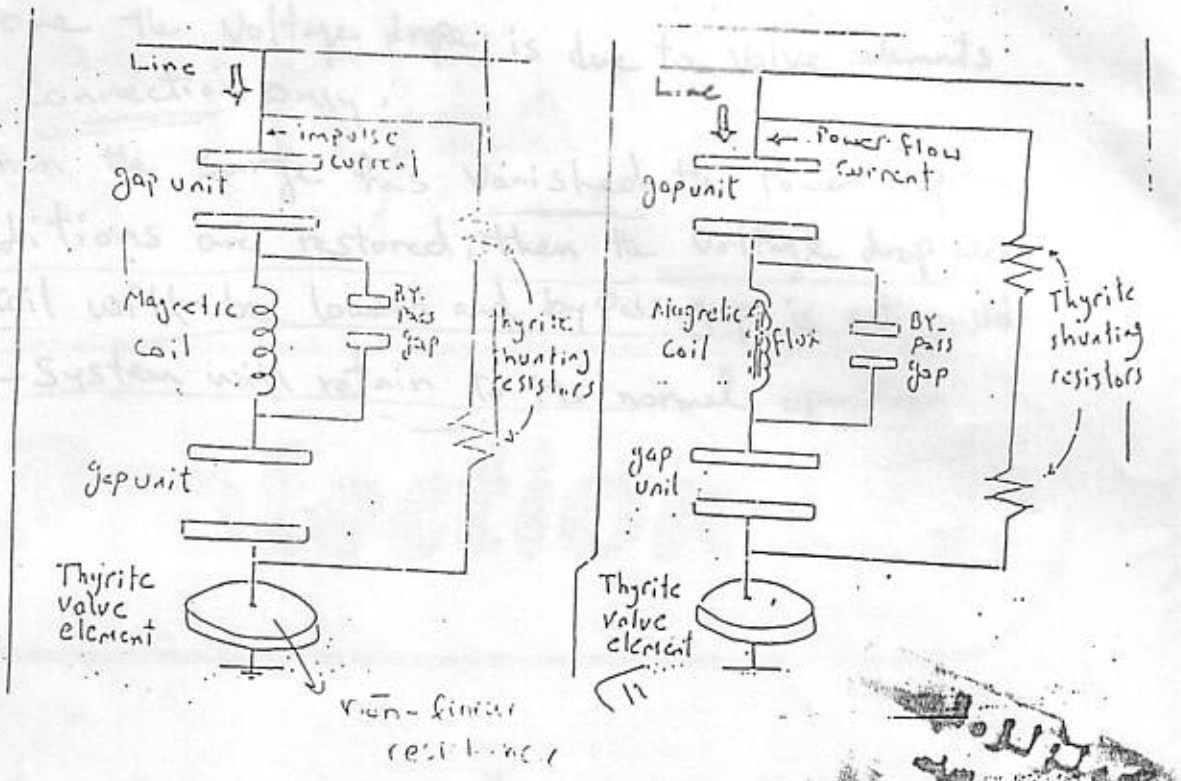


- Multiple spark gaps & in series & non-linear resistors are connected together.
- Non-linear resistor :-
  - i) For normal Power System Voltage its resistance is high.
  - ii) For discharge current its resistance is low.

Operation :-

1. When an overvoltage occurs the gap breaks down, the resistance is low, therefore the surge is diverted to earth.
2. After a few Msec. The surge vanishes and normal Power frequency voltage is set up across the arrestor, the resistance to this voltage is very high; therefore the current reduces and voltage across the gap is no more sufficient to maintain the arc, then the normal condition is restored.

3] Surge diverters with active gaps :—



Operation :—

(1) When an over voltage occurs the two gap units will Break down.

(2) The surge current will Pass through the Coil & Thyrite Valve element.

(3) The surge current quickly develops across the coil a voltage sufficient to cause bypass gap to flash over $L\frac{di}{dt} \uparrow \Rightarrow V_{coil} \uparrow$ ... for the Path of current will be by Pass gap → Thyrite Valve element

therefore the voltage drops is due to valve elements and connections only.

(4) When the surge has vanished the power frequency conditions are restored, then the voltage drop across the coil will be lowered and bypass gap is extinguished.

(5) The system will retain to its normal operation.

Protection (2)
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